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A COMPUTER CODE FOR FULLY-COUPLED ROCKET NOZZLE FLOWS (FULLNOZ)

H. S. Pergament, et al

AeroChem Research Laboratories, Incorporated

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A comprehensive computer code (FULLNOZ) has been developed to perform detailed calculations of rocket nozzle flows downstream of the sonic line. The code uses the streamtube method to integrate the hyperbolic governing equations of steady supersonic flow. The program represents a significant advance in nozzle flow predictions through the coupling of gas/particle nonequilibrium effects, nonequilibrium chemistry, turbulent boundary layers (to determine the effects of wall heat transfer and shear stress) and turbulent mixing across streamtubes.

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This report describes the analytical and numerical techniques employed by the code, presents results of a sample calculation for the Minuteman Stage 2 nozzle and gives complete instructions on the preparation of input data and a full FORTRAN listing.

Conditions of Reproduction

SUMMARY

This report describes the analytical and numerical techniques utilized in the development of a fully-coupled rocket nozzle flow computer code (FULLNOZ). The code uses the streamtube method to integrate the governing equations of steady supersonic flow. The elliptic Navier-Stokes equations are reduced to hyperbolic form by assuming diffusional effects along streamlines are small compared to those across streamlines. Finite difference techniques are then used to solve the hyperbolic equations along and perpendicular to streamlines.

FULLNOZ represents a significant advance in nozzle flow calculations by coupling the effects of nonequilibrium chemistry, gas/particle thermal and dynamic nonequilibrium, turbulent mixing across streamtubes and turbulent boundary layers. Turbulent mixing is treated via a phenomenological eddy viscosity model, while the turbulent boundary layer analysis utilizes the experimental data of Keener and Hopkins (which relates the compressible skin friction coefficient to measured velocity/temperature profiles in flows with favorable pressure gradients), the Van Driest transformations and the momentum integral equation. The operation of FULLNOZ requires the specification of initial gas and particle properties just downstream of the sonic line, the nozzle wall contour and temperature, and a chemical reaction mechanism and rate coefficients. The marching scheme proceeds downstream computing flow properties and composition along surfaces orthogonal to a specified number of streamtubes. A mixed explicit/implicit differencing scheme is used to obtain the most favorable integration step size.

Sample calculations are presented for the Minuteman Stage 2 nozzle. In addition, this report describes the preparation of input data and gives a full FORTRAN listing of the program. Also included is an analysis of heterogeneous electron/ion recombination on particles, although it has not as yet been incorporated into the code.

PREFACE

This is a report on the work performed on Contract F44620-74-C-0006 covering the period 1 September 1973 to 30 April 1975. It is basically a program user's manual for FULLNOZ, although some additional results obtained during this period, e.g. a preliminary study of how to incorporate heterogeneous electron-ion recombination into the code, have also been included.

The authors would like to thank J. T. Kelly for his initial work in the development of FULLNOZ and Capt. L. R. Lawrence, AFOSR Program Manager, for his interest, encouragement and support during the development of FULLNOZ.

This code is available for public use and may be obtained by forwarding a request and a tape to Lt. Robert Sperlein, DYSP, at the Air Force Rocket Propulsion Laboratory, Edwards Air Force Base, CA 93523.

This scientific report has been reviewed and is approved.

LIST OF SYMBOLS

A	streamtube area; also pre-exponential term in rate coefficient equations
$a_{i,jj}$	enthalpy-temperature polynomial coefficients, see Eq. (20)
B	activation energy
C_D	particle drag coefficient
$\bar{C}_D$	normalized drag coefficient, see Eq. (34)
$C_{D_{FM}}$	free molecular drag coefficient
C_{D_I}	high Reynolds number drag coefficient, see Eq. (35)
C_i	mass fraction of ith species
C_F	skin friction coefficient, see Eqs. (54) and (59)
C_p	gas specific heat
C_s	particle specific heat
D	diffusion flux, defined by Eq. (23)
$\bar{D}$	diffusion coefficient
F_i	defined as C_i/M_i
f_p	ratio of actual particle drag coefficient to the drag coefficient for Stokes flow
g_p	ratio of actual particle heat transfer coefficient to heat transfer coefficient for Stokes flow
H	gas stagnation enthalpy
H_{12}	shape factor, defined by Eq. (69)
H_f^o	heat of formation at 298°K
h	gas static enthalpy
h'	particle/gas heat transfer coefficient
I	total number of gas species
J	total number of particle groups
K_p	equilibrium constant
k	thermal (eddy) conductivity
k_f	forward reaction rate coefficient
k_g	molecular thermal conductivity in particle/gas interaction terms

L	total number of species on left or right side of reaction
L_1-L_5	specific heat polynomial coefficients
L_6	enthalpy constant of integration, see Eq. (31)
L_7	entropy constant of integration, see Eq. (32)
Le	turbulent Lewis number, $Le = \frac{C_p \bar{D} \rho}{k}$
M	Mach number
M_i	molecular weight of ith species
$\dot{m}$	streamtube mass flow, defined by Eq. (13)
N	number of reactions
Nu	Nusselt number, $Nu = \frac{h' r_p}{k_g}$
n	distance normal to streamline, also exponent in Eqs. (57) and (58)
Pr	turbulent Prandtl number, $Pr = \frac{\mu C_p}{k}$
Pr_g	laminar Prandtl number
p	static pressure
q	heat flux, defined by Eq. (22)
q_w	wall heat transfer, defined by Eq. (62)
R	universal gas constant, also value of nozzle radius at each x
Re	Reynolds number based on streamtube width
Re_p	particle Reynolds number
Re_x	Reynolds number based on distance along nozzle wall
Re_θ	Reynolds number based on boundary layer momentum thickness
r	radial distance from axis; also recovery factor, Eq. (49)
r_p	particle radius
s	distance along streamline
S	entropy
S_t	Stanton number, defined by Eq. (62)
T	static temperature
T_r	recovery temperature

u	velocity along streamline
U	velocity in boundary layer
U_τ	friction velocity, defined by Eq. (63)
V_p	particle velocity normal to gas streamline
$\dot{W}_i$	production rate of ith species
x	axial distance from nozzle starting line
y	distance from nozzle wall
Y	molar concentration

Greek Letters

α	numerical stability coefficient for marching scheme, see Eq. (29)
γ	ratio of specific heats
ΔG	Gibbs free energy
$\Delta_k(\Phi)$	change in Φ across streamtube
δ	boundary layer thickness
δ^*	displacement thickness
δn	finite difference mesh spacing in n direction
δs	finite difference mesh spacing in s direction
θ	angle between streamline and plume axis; also boundary layer momentum thickness
$\theta_s, \theta_s', \theta_s''$	respectively; final, initial and intermediate streamline radii of curvature
Φ	T/1000, used in Eq. (30)
ν	kinematic viscosity
ν'	stoichiometric coefficient on left hand side of reaction
ν''	stoichiometric coefficient on right hand side of reaction
μ	eddy viscosity
μ_g	molecular viscosity in particle/gas interaction terms
ρ	gas density
ρ_p	particle cloud density
ρ_s	density of liquid or solid particle
τ	shear stress, defined by Eq. (21) and Eq. (60)
Π	multiplication

$\sum$	summation

Subscripts

aw	adiabatic wall
c	compressible
e	wall streamtube
FM	free molecular
g	gas
i	ith species; also, incompressible
j	particle group identification index
k	streamtube index
l	orthogonal surface index; also refers to species on left or right hand side of reaction in Eq. (6)
m	mth reaction
n	differentiation in direction normal to streamlines
o	stagnation value
p	particle
s	differentiation in streamline direction
t	total
w	wall

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I. INTRODUCTION

This report describes a new fully-coupled rocket nozzle code (FULLNOZ) which treats, simultaneously, gas/particle nonequilibrium, nonequilibrium chemistry, diffusion across streamlines, and turbulent boundary layers within axisymmetric and two-dimensional nozzles. Because of its fully-coupled capability FULLNOZ can be applied to a wider range of problems than such existing rocket nozzle codes,† as TDK[1] (which does not account for gas/particle nonequilibrium effects), the nozzle portion of the CONTAM[2] code, the original constant γ gas/particle nonequilibrium code of Nickerson and Kliegel[3] and the recently-developed gas/particle and chemical nonequilibrium code developed at Lockheed/Huntsville.[4] The emphasis in the present code has been on an accurate calculation of nozzle exit plane gas and particle properties (particularly major and minor neutral and charged species concentrations), rather than on the determination of specific impulse, although FULLNOZ is well equipped to calculate I_{sp}.

---

† e.g. none of these codes calculate turbulent boundary layers.

1. "ICRPG Two-Dimensional Kinetic (TDK) Nozzle Analysis Computer Program," Dynamic Science Corp., December 1973 (revised version).

2. Hoffman, R.J., English, W.D., Oeding, R.G., and Webber, W.T., "Plume Contamination Effects Prediction: The CONTAM Computer Program," Final Report, Air Force Rocket Propulsion Laboratory, AFRPL-TR-71-109, December 1971.

3. Nickerson, G.R. and Kliegel, J.R., "Axisymmetric Two-Phase Perfect Gas Performance Program," TRW Systems Report No. 02874-6006-R000, Vols. I and II, April 1967.

4. Penny, M.M. and Smith, S.D., "Supersonic Gas-Particle Flows, Including Reacting Chemistry," JANNAF 8th Plume Technology Meeting, Colorado Springs, CO, July 1974.

FULLNOZ is based on the MULTITUBE code developed by Boynton,[5] which incorporates the streamtube method† (described by Boynton and Thomson[6]) to integrate the hyperbolic governing equations of steady supersonic flow. The major routines incorporated into FULLNOZ which are not in MULTITUBE include (1) particle/gas nonequilibrium, (2) nonequilibrium chemistry and (3) turbulent wall boundary layers. Briefly, in the streamtube method the elliptic Navier-Stokes equations‡ are reduced to hyperbolic form by assuming that diffusional effects along streamlines are small compared to diffusion across streamlines. This assumption is very good for rocket nozzle (and plume) flows and enables one to solve an initial value problem (where a marching procedure can be used) rather than the more difficult boundary value problem. The gas flow equations, in finite-difference form, are solved along and perpendicular to streamlines while a full continuum particle cloud system of equations is incorporated for the condensed phase.

The advantages of using the streamtube method over the method of characteristics in calculating rocket nozzle (and plume) flows are:

- Species diffusion, shear, and heat transfer normal to streamlines are easily included.
- Chemical reactions or internal relaxations are easily incorporated since the calculation follows streamlines.
- Bounding surfaces and gradients normal to streamlines are treated without difficulty; and
- A wide variety of boundary conditions including mass transfer, shear and heat transfer can readily be incorporated.

---

† In contrast to the abovementioned codes,[1-4] which all use the method of characteristics.

‡ In using the Navier-Stokes equations as a base the technique can readily be extended, with the proper boundary conditions, to low density nozzle flows.

5. Boynton, F.P., "The MULTITUBE Supersonic Flow Computer Code," General Dynamics/Convair GDC-DBB 67-003, February 1967.

6. Boynton, F.P. and Thomson, A., "Numerical Computation of Steady, Supersonic, Two-Dimensional Gas Flow in Natural Coordinates," J. Computational Phys. 3, 379-398 (1969).

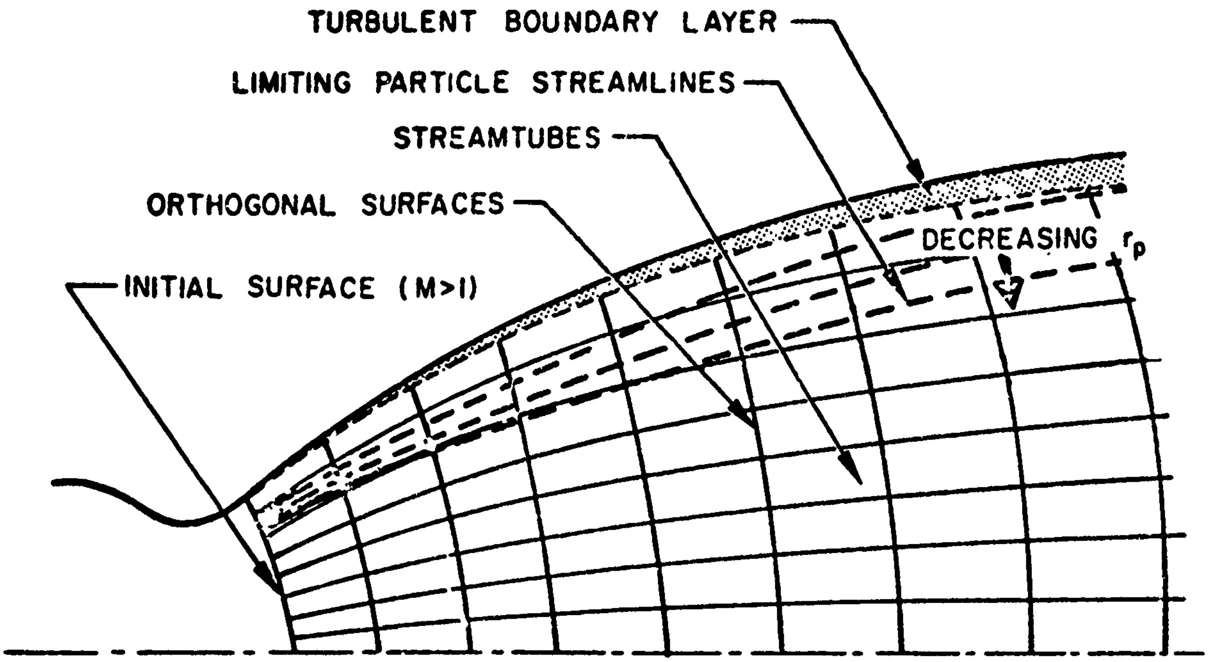

Figure 1. FULLNOZ schematic.

Operation of the code is achieved by specifying (1) initial gas and particle properties in the supersonic region just downstream of the nozzle throat,† (2) the nozzle wall contour, (3) a chemical reaction mechanism and rate coefficients, (4) physical properties of the particles, and (5) the nozzle wall temperature (for the boundary layer calculations). With the above input data the marching scheme steps from one orthogonal surface to the next (Fig. 1) computing gas and particle properties within a specified number of streamtubes. The (essentially) continuous particle size distribution is represented by up to a maximum of 8 discreet particle sizes. All particles cross the gas streamlines, but the lighter particles follow the gas streamlines more closely than the heavy particles. As depicted in Fig. 1, limiting particle streamlines are computed for each particle size. At each orthogonal surface (i.e. each integration

† It would be useful to incorporate an "initializing" scheme which utilizes combustion chamber properties as initial conditions, computes flow properties through the transonic region and establishes an initial supersonic data line. Such a scheme, developed by Nickerson and Kliegel,[3] is contained in the codes of Refs. 1-3, and with additional programming could be inserted into FULLNOZ.

step) the code calculates wall shear stress and heat transfer, boundary layer displacement thickness and velocity and temperature profiles. The shear stress and heat transfer are coupled to the main nozzle flow via their effect on the wall streamtube properties.† The turbulent boundary layer analysis utilizes the Van Driest[7] transformations and the experimental data of Keener and Hopkins,[8] which relates the compressible skin friction coefficient to measured velocity/temperature profiles in flows with favorable pressure gradients (see Section II.C.4). The boundary layer momentum thickness is computed via the momentum integral equation, using the wall streamtube pressure, velocity, etc., as the boundary layer 'edge' conditions. The displacement thickness is then determined from the velocity profile and momentum thickness.

The code will not handle shocks that might originate from the nozzle wall in turning the flow. The flow in the region of the shock will be treated as a strong compression wave.‡

---

† This implicitly assumes that the boundary layer momentum and energy thicknesses are smaller than the wall streamtube thickness. This will generally be true for high Reynolds number nozzle flows. Provision is in the program, however, to transfer momentum, heat and mass across streamtubes, so that if an appropriate transfer coefficient can be defined the boundary layer effects can be "felt" throughout the flow.

‡ Nozzle shocks could be incorporated into FULLNOZ in a manner similar to that employed in the AIPP code[9,10] to detect internal plume shocks, but this would require additional programming.

7. Van Driest, E.R., "Turbulent Boundary Layer in Compressible Fluids," J. Aeron. Sci. 18, 145-160 (1951).

8. Keener, E.R. and Hopkins, E.J., "Van Driest Generalization Applied to Turbulent Skin Friction and Velocity Profiles Measured on the Wall of a Mach 7.4 Wind Tunnel," AIAA J. 11, 1784-1785 (1973).

9. Pergament, H.S. and Kelly, J.T., "A Fully-Coupled Underexpanded Rocket Plume Program. (The AIPP Code). Part I. Analytical and Numerical Techniques," AeroChem TP-302a, AFPRL-TR-74-59, November 1974.

10. Pergament, H.S. and Kelly, J.T., "A Fully-Coupled Underexpanded Rocket Plume Program (The AIPP Code). Part II. Program User's Manual," AeroChem TP- (in preparation).

The code was written for operation on a CDC 6400 computer and requires approximately 122 K (octal) of core storage. For operation on machines with larger core storage the user may want to increase the dimension of some parameters, such as total number of species (25 maximum) and total number of reactions (40 maximum).

This report serves primarily as a program user's manual,† but also contains all the governing equations (Section II) and the results of some preliminary parametric calculations for the Minuteman, second stage nozzle (Section IV.A). The user should be cautioned that, although the code has been formally debugged for several test cases, extensive calculations have not (as of April 1975) been made; therefore some operational problems may be experienced. If these do occur, please contact the authors.

II. GOVERNING EQUATIONS

This section gives the governing differential and finite-difference equations used in the code. Also included are the auxiliary equations for calculating thermodynamic and chemical kinetic properties of the system, gas/particle drag and heat transfer coefficients and turbulent boundary layer properties.

A. Differential Equations

1. Gas Phase

For most high Reynolds number nozzle flows of interest the turbulent transport of mass, momentum and energy throughout the main nozzle flow will be negligible. Thus in the equations that follow all transport terms will be identically zero. In practice this is achieved by setting ITURB (Card 4, Cols. 56-60) equal to zero. If turbulent diffusion across streamtubes is to be included due either to initial non-uniformities or to the propagation of boundary layer effects across the flow, appropriate (constant) values of the eddy transport terms, μ, Pr and Le will have to be input on Card 10. If a suitable expression for eddy viscosity in terms of local properties can be developed for transport across streamtubes within nozzles, this expression can easily be added to the program in subroutine TRANSP.

---

† The same numerical integration techniques and similar program logic is incorporated into the AIPP code,[9,10] to which the reader is referred for additional information on program subroutines.

Global Continuity

$$(\rho u)_s + \rho u \frac{\sin\theta}{r} + \rho u \theta_n = 0 \qquad (1)$$

s-Momentum

$$\rho u u_s + p_s = \frac{1}{r}\left[r \mu u_n \right]_n - \sum_{j=1}^{J} \frac{9}{2} \frac{\rho_{p_j} f_{p_j} \mu_g}{\rho_s r_{p_j}^2} \left(u - u_{p_j}\right) \qquad (2)$$

n-Momentum

$$\rho u^2 \theta_s + p_n = \sum_{j=1}^{J} \frac{9}{2} \frac{\mu_g \rho_{p_j} f_{p_j}}{\rho_s r_{p_j}^2} V_{p_j} \qquad (3)$$

Species Continuity†

$$\rho u (C_i)_s = \rho \dot{W}_i + \frac{1}{r}\left[r \mu \frac{Le}{Pr} (C_i)_n \right]_n \qquad (4)$$

Energy

$$\rho u H_s = \frac{1}{r}\left[r \frac{\mu}{Pr} H_n \right]_n + \frac{1}{r}\left[\left(1 - \frac{1}{Pr}\right)\mu \left(\frac{u^2}{2}\right)_n r \right]_n$$

$$+ \frac{1}{r}\left[\sum_{i=1}^{I} \left\{ \frac{\mu}{Pr} \left(Le - 1\right) r \; h_i \, (C_i)_n \right\} \right]_n$$

$$+ \sum_{j=1}^{J} \frac{9}{2} \frac{\mu_g \rho_{p_j} f_{p_j}}{\rho_s r_{p_j}^2} \left\{ V_{p_j}^2 + \left(u - u_{p_j}\right)^2 \right.$$

$$\left. + \frac{2}{3} \frac{g_{p_j}}{f_{p_j}} \frac{C_p}{Pr_g} \left(T_{p_j} - T\right) \right\} \qquad (5)$$

---

†In this formulation, $\dot{W}_i$ is expressed in units of $\sec^{-1}$.

The drag (f_{p_j}) and heat transfer (g_{p_j}) factors are defined as, $f_{p_j} = C_D Re_p/24$ and $g_{p_j} = (Nu/2)(T_p - T_r)/(T_p - T)$, where T_r is the recovery temperature based on the relative velocity between the gas and particle.

The following auxiliary expressions are required:

Species Production

$$\dot{W}_i = \frac{M_i}{\rho} \sum_{m=1}^{N} \left(\nu''_{i,m} - \nu'_{i,m}\right) \left[k_{fm} \prod_{\ell=1}^{L} Y_\ell^{\nu'_{\ell,m}} - \frac{k_{fm}}{K_p} \prod_{\ell=1}^{L} Y_\ell^{\nu''_{\ell,m}}\right] \tag{6}$$

Equation of State

$$\rho = \frac{p}{RT \sum_i \frac{C_i}{M_i}} \tag{7}$$

Stagnation Enthalpy

$$H = \frac{u^2}{2} + h(T) \tag{8}$$

2. Particles

For the condensed phases present within the flow a continuum particle cloud assumption is made and therefore field conservation equations for continuity, momentum and energy can be written for the particles. The (essentially) continuous distribution of particle sizes at each point in the flow is modeled by several groups of constant size particles representative of the distribution. For a given group, j, the conservation equations, written in a streamline oriented coordinate system are:

Continuity

$$(r \rho_{p_j} u_{p_j})_s + (r \rho_{p_j} V_{p_j})_n + r \rho_{p_j} u_{p_j} \theta_n - r \rho_{p_j} V_{p_j} \theta_s = 0 \qquad (9)$$

s-Momentum

$$u_{p_j}(u_{p_j})_s + V_{p_j}(u_{p_j})_n - V_{p_j}(V_{p_j}\theta_n - u_{p_j}\theta_s) =$$

$$- \frac{9}{2} \frac{\mu_g f_{p_j}}{\rho_s r_{p_j}^{2}} \left(u_{p_j} - u\right) \qquad (10)$$

n-Momentum

$$u_{p_j}(V_{p_j})_s + V_{p_j}(V_{p_j})_n + u_{p_j}(V_{p_j}\theta_n + u_{p_j}\theta_s) =$$

$$- \frac{9}{2} \frac{\mu_g f_{p_j}}{\rho_s r_{p_j}^{2}} V_{p_j} \qquad (11)$$

Energy[†]

$$u_{p_j}(C_s T_{p_j})_s + V_{p_j}(C_s T_{p_j})_n = - \frac{3 k_g g_{p_j}}{r_{p_j}^2 \rho_s} \left(T_{p_j} - T\right) \qquad (12)$$

[†] The effects of chemical reactions on the surface of particles are not included in this analysis.

When the particle undergoes a phase change (liquid to solid) it is kept at the solidification temperature until the total heat of solidification is released (via radiative and convective heat transfer) to the gas.

B. Finite-Difference Equations

A finite difference formulation of the gas phase and particle cloud governing equations is utilized on a grid which lies along and perpendicular to the streamlines.

1. Gas-Phase

The momentum and energy equations (Eqs. (2), (3) and (5)) are solved via an explicit finite-difference marching technique, whereas the species continuity equation (Eq. (4)), utilizes an implicit finite difference formulation developed in an earlier study at AeroChem.[11] This mixed form of the difference equations is necessary for the economical operation of the present code since, for near-equilibrium chemistry, the explicit finite-difference form of Eq. (4) leads to stability-limited (impractically small) integration step sizes. Equations (2), (3) and (5) are left in explicit form since the required integration step sizes for stability are reasonable; an implicit formulation of these equations would unnecessarily complicate the calculations.

To minimize the effects of large tube-to-tube property variations on the calculation of streamline curvature, a Von Mises-type transformation is employed, i.e.

$$\dot{m} = 2\pi \int \rho\, u r\, dn \tag{13}$$

Using Eq. (13) the finite difference forms of the differential equations become:

Global Continuity

$$\dot{m}_k = \rho_{k,\ell+1} u_{k,\ell+1} A_{k,\ell+1} \tag{14}$$

---

11. Mikatarian, R.R., Kau, C.J., and Pergament, H.S., "A Fast Computer Program for Nonequilibrium Rocket Plume Predictions," Final Report, AeroChem TP-282, AFRPL-TR-72-94, August 1972.

s-Momentum

$$\dot{m}_k(u_{k,\ell+1} - u_{k,\ell}) + \frac{1}{2}(A_{k,\ell+1} + A_{k,\ell})(p_{k,\ell+1} - p_{k,\ell}) =$$

$$\Delta_k(r_k \tau_k \delta s_k)\, 2\pi - \frac{1}{2}\left(A_{k,\ell+1} + A_{k,\ell}\right)$$

$$\times \sum_{j=1}^{J} \frac{9}{2}\left(\frac{\rho_{p_j} f_{p_j} \mu_g}{\rho_s r_{p_j}^2}\right)_{k,\ell}\left(u_{k,\ell} - u_{p_{j\,k,\ell}}\right) \tag{15}$$

n-Momentum

$$\left(\frac{\partial\theta}{\partial s}\right)_{k,\ell} = -\frac{8\pi\, r_{k,\ell}}{u_{k,\ell} + u_{k+1,\ell}}\left(\frac{p_{k+1,\ell} - p_{k,\ell}}{\dot{m}_k + \dot{m}_{k+1}}\right)$$

$$+ \frac{2}{\left((\rho u^2)_{k+1,\ell} + (\rho u^2)_{k,\ell}\right)}$$

$$\times \sum_{j=1}^{J} \frac{9}{2}\left(\frac{\rho_{p_j} f_{p_j} \mu_g}{\rho_s r_{p_j}^2}\right)_{k,\ell} V_{p_{j\,k,\ell}} \tag{16}$$

Species Continuity†

$$\dot{m}_k(C_{i,k,\ell+1} - C_{i,k,\ell}) = \Delta_k(r_k D_{i,k}\, \delta s_k)\, 2\pi + \frac{2\, \dot{m}_k\, \delta s_k}{(u_{k,\ell+1} + u_{k,\ell})}\dot{W}_{i_k} \tag{17}$$

---

†The species mass fractions at station $k,\ell+1$ ($C_{i,\ k,\ell+1}$) are determined by linearizing the chemistry terms ($(\dot{W}_i)_k$) and inverting the resulting matrix (see Ref. 11).

Energy

$$\dot{m}_k \left(h_{k,\ell+1} - h_{k,\ell} + \frac{1}{2} u^2_{k,\ell+1} - \frac{1}{2} u^2_{k,\ell}\right) =$$

$$\Delta_k \left(r_k \left[q_k + \left(\frac{1}{2}(u_k^2 + u_{k+1}^2)\right)^{1/2} \tau_k + \sum_{i=1}^{I} h_{i,k} D_{i,k} \right] \delta s_k \right) 2\pi$$

$$+ \frac{1}{2} (A_{k,\ell+1} + A_{k,\ell}) \sum_{j=1}^{J} \left(\frac{9}{2} \left(\frac{\rho_{p_j} f_{p_j} \mu_g}{\rho_s r_{p_j}^2} \right)_{k,\ell} \left[V_{p_j\,k,\ell}^2 \right.\right.$$

$$\left.\left. + (u^2_{k,\ell} - u^2_{p_j\,k,\ell}) + \frac{2}{3} \left(\frac{g_{p_j} C_{p_g}}{f_{p_j} Pr} \right)_{k,\ell} \left(T_{p_j\,k,\ell} - T_{k,\ell} \right) \right] \right) \tag{18}$$

State

$$\rho_{k,\ell} = \frac{P_{k,\ell}}{R\, T_{k,\ell} \sum_i \left(\frac{C_i}{M_i}\right)_{k,\ell}} \tag{19}$$

Enthalpy

$$H = \frac{u^2_{k,\ell}}{2} + \sum_i \sum_{jj} a_{i,jj}\, T^{jj-1}_{k,\ell}\, C_{i_{k,\ell}} \tag{20}$$

where in Eqs. (15), (17) and (18),

$$\tau_k = -2\pi\, r_k\, 2(u^2_{k+1,\ell} - u^2_{k,\ell}) \frac{\left(\rho_{k,\ell}\mu_{k,\ell} + \rho_{k+1,\ell}\mu_{k+1,\ell}\right)}{\left(\dot{m}_{k+1} + \dot{m}_k\right)} \tag{21}$$

and

$$q_k = -2\pi\, r_k\, 2(u_{k+1,\ell} + u_{k,\ell}) \times \frac{\left(\rho_{k,\ell}\, k_{k,\ell} + \rho_{k+1,\ell}\, k_{k+1,\ell}\right)\left(T_{k+1,\ell} - T_{k,\ell}\right)}{\left(\dot{m}_{k+1} + \dot{m}_k\right)} \tag{22}$$

and

$$D_{i,k} = -\frac{2\pi\, r_k\, 2\left(u_{k+1,\ell} + u_k\right)\left(\rho^2_{k+1,\ell}\, \overline{D}_{k+1,\ell} + \rho^2_{k,\ell}\, \overline{D}_{k,\ell}\right)\left(C_{i,k+1,\ell} - (C_{i,k,\ell}\right)}{\left(\dot{m}_{k+1} + \dot{m}_k\right)} \tag{23}$$

2. Particles

The finite difference forms of Eqs. (9-12) are:

Continuity

$$(r\rho_{p_j} u_{p_j})_{k,\ell+1} - (r\rho_{p_j} u_{p_j})_{k,\ell} + \left((r\rho_{p_j} V_{p_j})_{k+1,\ell} - (r\rho_{p_j} V_{p_j})_{k,\ell} \right) \frac{\delta s_k}{\delta n_k}$$

$$+ \delta s_k (r\rho_{p_j} u_{p_j})_{k,\ell}\, \Theta_{n_{k,\ell}} - \delta s_k (r\rho_{p_j} V_{p_j})_{k,\ell}\, \Theta_{s_{k,\ell}} = 0 \tag{24}$$

s-Momentum

$$u_{p_{jk,\ell}}(u_{p_{jk,\ell+1}} - u_{p_{jk,\ell}}) + V_{p_{jk,\ell}}(u_{p_{jk+1,\ell}} - u_{p_{jk,\ell}}) \frac{\delta s_k}{\delta n_k}$$

$$- \delta s_k V_{p_{jk,\ell}}(V_{p_j}\theta_n - u_{p_j}\theta_s)_{k,\ell} =$$

$$- \frac{9}{2}\left(\frac{f_{p_j}\mu_g}{\rho_s r_{p_j}^2}\right)_{k,\ell}(u_{p_{jk,\ell}} - u_{k,\ell})\delta s_k \tag{25}$$

n-Momentum

$$u_{p_{jk,\ell}}(V_{p_{jk,\ell+1}} - V_{p_{jk,\ell}}) + V_{p_{jk,\ell}}(V_{p_{jk+1,\ell}} - V_{p_{jk,\ell}}) \frac{\delta s_k}{\delta n_k}$$

$$+ u_{p_{jk,\ell}}(V_{p_j}\theta_n + u_{p_j}\theta_s)_{k,\ell}\ \delta s_k =$$

$$- \frac{9}{2}\left(\frac{\mu_g f_{p_j}}{\rho_s r_{p_j}^2}\right)_{k,\ell} V_{p_{jk,\ell}}\ \delta s_k \tag{26}$$

Energy

$$u_{p_{jk,\ell}} C_s(T_{p_{jk,\ell+1}} - T_{p_{jk,\ell}}) + V_{p_{jk,\ell}} C_s(T_{p_{jk+1,\ell}} - T_{p_{jk,\ell}}) \frac{\delta s_k}{\delta n_k} =$$

$$- \frac{3\epsilon\sigma}{r_{p_{jk,\ell}}\rho_s} T_{p_{jk,\ell}}^4 \delta s_k - 3\left(\frac{k_g g_{p_j}}{r_{p_j}^2 \rho_s}\right)_{k,\ell}$$

$$\times (T_{p_{jk,\ell}} - T_{k,\ell})\delta s_k \tag{27}$$

3. Integration Step Size

The integration step size must be limited in order to perform a stable calculation. The stability of the explicit finite difference scheme for solving the gas dynamic equations is discussed by Boynton and Thomson,[6] who show that the stable step size for laminar flow is determined from,

$$\delta s \leq \frac{\delta n}{2}\left[\frac{1}{Re} + \frac{1}{(M^2 - 1)^{1/2}}\right]^{-1} \tag{28}$$

For turbulent flow the eddy viscosity replaces the laminar viscosity in the expression for Re.† The step size determined from Eq. (28) may not be sufficiently small if the chemistry is very "fast". Thus, an additional "chemistry" control has been incorporated into the code: at each integration step (orthogonal surface) the species mass fractions are tested for sign. If any C_i goes negative the integration step size is halved and the calculations are repeated until the C_i in question becomes positive or the step size becomes less than the minimum allowable step size. In the latter case the program terminates.

The particle cloud system of equations (Eqs. (9-12)) contains derivatives related only to the convection of mass, momentum and energy. In the momentum and energy equations, the convection terms are equal to the particle/gas interaction terms. Unlike the gas flow equations the particle equations have no wave or diffusive nature. Consequently when these equations are solved explicitly there is no stability limitation on the integration step size and the step size can be determined from Eq. (28).

4. Solution Procedure

The gas phase and particle cloud finite difference equations are solved on a grid consisting of the streamtubes and the surfaces orthogonal to them, as illustrated in Fig. 1. All gas and particle flow properties, streamline positions and angles must be known along the initial orthogonal surface downstream of the throat ($M > 1$). Starting with the first streamtube (adjacent to the axis) the streamtubes are extended a distance δs to a downstream surface, utilizing the radius of curvature, $(\Theta_s)'$ obtained from the normal momentum equation (Eq. (16)) and the known initial pressure distribution along the

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† Eq. (28) is not, of course, valid in the limit, $Re \to 0$. In that case (i.e. the situation for most practical nozzle flows), $\delta s \leq \frac{\delta n}{2}[M^2-1]^{1/2}$.

surface. The resulting streamtube areas are then used to determine all the necessary gas properties at the downstream surface from Eqs. (14), (15), and (17)-(23). The transfer of mass, momentum and energy into or out of each streamtube is arranged such that what is lost from a given streamtube is gained by the adjacent tube. Thereby mass, momentum and energy are automatically conserved.

In order to render this marching scheme conditionally stable a single iteration on the radius of curvature calculation is required,[6] with the new value, $(\Theta_s)''$, determined using the downstream surface properties. $(\Theta_s)''$ is then combined with $(\Theta_s)'_k$ in the following expression,[6]

$$(\Theta_s) = (1 - \alpha)(\Theta_s)' + \alpha(\Theta_s)'' \tag{29}$$

This new value for the radius of curvature is then used in the calculation. A value for α of 0.55 is used in the present code. (The scheme is conditionally stable for $\alpha \geq 1/2$).

After the gas phase equations have been solved for the first streamtube the particle properties are determined by sequentially applying the particle momentum, continuity and energy equations. The calculation of gas and particle properties then moves outward to the next streamtube and the procedure is repeated up to the last streamtube† where boundary conditions must be applied.

C. Auxiliary Calculations

1. Thermodynamic Input Data

The thermodynamic data are input via curve fits of specific heats[12] of individual species in the JANNAF tables.[13] These curve fits have the form,

$$C_{p_i} = L_{1_i} + L_{2_i}\Phi + L_{3_i}\Phi^2 + L_{4_i}\Phi^3 + L_{5_i}\Phi^{-2} \quad \text{cal/mole-}^\circ\text{K} \tag{30}$$

† In general the limiting particle streamlines for each particle size will not extend to the last streamtube.

12. Cruise, D.R., "Information Manual for the Theoretical Propellant Evaluation Program," Naval Weapons Center PEP NOTE TN-U-1 (plus additions), December 1964.

13. JANNAF Thermochemical Tables (Dow Chemical Company, Midland, Mich.), continuously updated.

where $\Phi = T(^{o}K)/1000$. The enthalpy is then expressed as,

$$h_i = \int_0^T C_{p_i} \, dT + L_{6_i} \qquad \text{kcal/mole} \qquad (31)$$

where $L_{6_i} = H_f^0 - \int_0^{298} C_{p_i} \, dT$; H_f^0 being the heat of formation at 298°K. The entropy is expressed as,

$$S_i = \int_0^T C_{p_i} \frac{dT}{T} + L_{7_i} \qquad \text{cal/mole-}^{o}\text{K} \qquad (32)$$

where L_{7_i} is the entropy integration constant. The coefficients L_1 - L_7 are input on Card group 8.

2. Chemical Kinetic Input Data

Ten possible reaction types are included in the program:

Reaction Type

(1)	A + B	$\rightleftarrows$ C + D
(2)	A + B + M	$\rightleftarrows$ C + M
(3)	A + B	$\rightleftarrows$ C + D + E
(4)	A + B	$\rightleftarrows$ C
(5)	A + M	$\rightleftarrows$ C + D + M
(6)	A + B	$\rightarrow$ C + D
(7)	A + B + M	$\rightarrow$ C + M
(8)	A + B	$\rightarrow$ C + D + E
(9)	A + B	$\rightarrow$ C
(10)	A + M	$\rightarrow$ C + D + M

Reaction types (6)-(10) correspond to reaction types (1)-(5), but proceed in the forward direction only. In Reactions (2), (5), (7) and (10), M is an arbitrary third body. In this program, all species are assumed to have equal third body efficiencies.

The forward rate coefficient, k_f, is input to the code as one of the following 8 types

Rate Coefficient Type†

(1) $k_f = A$

(2) $k_f = AT^{-1}$

(3) $k_f = AT^{-2}$

(4) $k_f = AT^{-\frac{1}{2}}$

(5) $k_f = A \exp(B/RT)$

(6) $k_f = AT^{-1} \exp(B/RT)$

(7) $k_f = AT^{-\frac{3}{2}}$

(8) $k_f = AT^{N} \exp(B/RT)$

The equilibrium constant, K_p, is determined from

$$\ln K_p = - \Delta G/RT \tag{33}$$

where the Gibbs free energy, ΔG, for individual reactions is computed from the input thermodynamic data.

† Rate coefficient data for typical rocket nozzle and plume reactions may be found, e.g., in Ref. 14.

14. Jensen, D.E. and Jones, G.A., "Gas-Phase Reaction Rate Coefficients for Rocketry Applications," Rocket Propulsion Establishment Technical Report No. 71/9, October 1971.

3. Particle/Gas Drag and Heat Transfer Coefficients

The momentum and energy exchange (via convective heat transfer) between the small diameter particles and the combustion products in the nozzle cannot adequately be described by simple theoretical expressions (e.g. Stokes law).[15] Empirical correlations of drag and heat transfer coefficients developed by Crowe[16] have therefore been incorporated in the particle/gas interaction terms (see, e.g. Eqs. (2), (3), and (5)).

a. Drag Coefficient - The drag coefficient has been correlated by Crowe[16] in terms of a normalized value,

$$\bar{C}_D = (C_D - C_{D_I})/(C_{D_{FM}} - C_{D_I}) \tag{34}$$

where C_{D_I} is the drag coefficient at very large Reynolds number and $C_{D_{FM}}$ is the free molecular drag coefficient. Note that for $Re_p << 1$, $\bar{C}_D \to 1$, while for $Re_p >> 1$, $\bar{C}_D \to 0$.

The expressions needed to evaluate C_D from Eq. (32) are:

$$C_{D_I} = 0.66 + 0.26\,[\exp(4\ \ln M_p) - 1] + 0.17\,\exp[-2.5(\ln M_p/1.4)^2] \tag{35}$$

$$C_{D_{FM}} = \frac{\exp(-S_1^2/2)}{\sqrt{\pi}\ S_1^3}(1 + 2S_1^2) + \frac{4(S_1^4 + S_1^2) - 1}{2S_1^4}\ \mathrm{erf}(S_1) + \frac{2}{3}\frac{\sqrt{\pi}}{\sqrt{T/T_p}} \tag{36}$$

where,

$$S_1 = \sqrt{\gamma/2}\ M_p \tag{37}$$

$$\bar{C}_D = G(Kn)\ D(Kn,\ Re_p) \tag{38}$$

$$G(Kn) = \frac{Kn^{0.4}\exp(1.2\ Kn^{0.5})}{1 + Kn^{0.4}\exp(1.2\ Kn^{0.5})} \tag{39}$$

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15. Soo, S. L., Fluid Dynamics of Multiphase Systems (Blaisdell Publ. Co, Waltham, Mass., 1967).

16. Crowe, C. T., "On the Momentum and Heat Transfer Equations for Two-Phase Plumes," Washington State Univ., March 1971.

and

$$D(Kn, Re_p) = 1 - \exp\left[- \frac{Re_p}{8} Kn^{0.6} \exp(Kn) \left(C_{D_o} - 0.4 \right) \right] \tag{40}$$

$$Kn = 1.26 \sqrt{\gamma} \frac{M_p}{Re_p} \tag{41}$$

and, $$C_{D_o} = 24/Re_p \tag{42}$$

The expression used in the particle/gas interaction terms is then,

$$f_p = FFF \frac{C_D}{C_{D_o}} \tag{43}$$

where FFF is a factor (input on Card 15, Cols. 1-10) used to arbitrarily vary C_D to account for uncertainties in the above analysis.

b. Heat Transfer Coefficient - Heat transfer from the particle to the gas is expressed in terms of a Nusselt number as,

$$q = 2\pi r_p Nu\, k(T_p - T_r) \tag{44}$$

where T_r is the recovery temperature. From Crowe[16] we get the following expression,

$$Nu = Nu_{KD} + \frac{\gamma + 1}{\gamma} Re_p Pr_g \exp(-Re_p/2M_p) \tag{45}$$

$$Nu_{KD} = Nu_o/\left(1 + \frac{5\gamma^{1.5}}{\gamma + 1} (M_p/Re_p Pr_g) Nu_o \right) \tag{46}$$

Nu_o is the Nusselt number in incompressible flow, expressed as

$$Nu_o = 2.0 + 0.459 Re_p^{0.55} Pr_g^{0.33} \tag{47}$$

The recovery temperature is defined as,

$$Tr = T + r\left((u - u_p)^2 + V_p{}^2 \right)/2C_p \tag{48}$$

where the recovery factor r is[16];

$$r = 0.9 + (r_{FM} - 0.9)\exp(-Re_p/2M_p) \tag{49}$$

and

$$r_{FM} = \frac{\gamma}{\gamma+1}\left(2 + 0.67\exp(-M^2/3)\right) \tag{50}$$

The expression used in the particle/gas interaction term is,

$$g_p = FFG\,\frac{Nu}{2}\,\frac{T_p - T_r}{T_p - T} \tag{51}$$

where FFG is a factor (input on Card 15, Cols. 11-20) used to arbitrarily vary g_p to account for uncertainties in the above analysis.

D. Turbulent Boundary Layer Equations†

The turbulent compressible boundary layer analysis is initiated by calculating the corresponding adiabatic flat plate, zero pressure gradient, incompressible boundary layer properties, based on a 1/7 power law[17]

† The "free stream" properties (subscript "e") for the boundary layer analysis are taken to be the properties in the last (wall) streamtube. It is implicitly assumed that the boundary layer displacement thickness is smaller than the width of the wall streamtube.

17. Schlicting, H., Boundary Layer Theory, 6th Ed. (McGraw-Hill, New York, 1968), p. 599.

velocity profile.† Expressions for the incompressible momentum and boundary layer thickness are,

$$\theta_i(x) = 0.036/Re_x^{0.2} \tag{52}$$

$$\delta_i(x) = 10.286\,\theta_i(x) \tag{53}$$

The incompressible skin friction coefficient is evaluated from the Karman-Schoenherr relation.[20]

$$C_{F_i} = [17.08\,(\log_{10} Re_{\theta_i})^2 + 25.11\,\log_{10} Re_{\theta_i} + 6.012]^{-1} \tag{54}$$

Transformation from the compressible to the incompressible boundary layer is accomplished via the Van Driest equations,[7] which relate the velocity and temperature profiles as follows,

$$\bar{T}_t = \frac{T_e - T_w}{T_{t_e} - T_w} = f\left(\frac{U}{U_e}\right) \tag{55}$$

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† It was originally anticipated that the complete boundary layer equations including nonequilibrium chemistry would be solved by finite differences and coupled to the nozzle flow solution. A number of boundary layer codes are available, including those of Herring and Mellor[18] and the Aerotherm BLIMP code,[19] which would be very useful for this purpose. However, initial attempts to incorporate the BLIMP code into FULLNOZ showed that it would take more effort than was warranted at this time. Consequently, a more simplified analysis was incorporated into the present code.

18. Herring, H.J. and Mellor, G.L., "A Method of Calculating Compressible Turbulent Boundary Layers," NASA CR-1144, September 1968.

19. Tong, H., Buckingham, A.C., and Morse, H.L., "Nonequilibrium Chemistry Boundary Layer Integral Matrix Procedure," Aerotherm Final Report No. 73-67, July 1973.

20. Hopkins, E.J., Keener, E.R., and Louie, P.T., "Direct Measurements of Turbulent Skin Friction on a Nonadiabatic Flat Plate at Mach Number 6.5 and Comparisons with Eight Theories," NASA TN D-5675, February 1970.

The general functional relation used in the analysis is

$$\bar{T}_t = \left(\frac{U}{U_e}\right)^n \tag{56}$$

Equation (56) becomes the Crocco relation for n = 1 and the quadratic for n = 2.

A general expression between T/T_e and U/U_e can then be written

$$\frac{T}{T_e} = A\left(\frac{U}{U_e}\right)^2 + B\left(\frac{U}{U_e}\right)^n + C \tag{57}$$

where

$$A = \left(\frac{T_{t_e}}{T_e} - 1\right);\ B = \left(\frac{T_{t_e}}{T_e} - \frac{T_w}{T_e}\right);\ C = \frac{T_w}{T_e}$$

From Back and Cuffel,[21] wall cooling ($T_w < T_{aw}$) tends to make the exponent n closer to 1.0, while wall heating causes n to approach 2 or more. The value of n selected here was 1.2. It was determined by fitting recent data of Keener and Hopkins[8] for which, $T_w/T_{aw} = 0.32$. (This corresponds to a wall temperature of 1000-1300 K.) Equation (57) was used to generate a table of T/T_e vs. U/U_e, which is then used to determine the compressible skin friction coefficient via the Van Driest transformation

$$\frac{C_{f_c}}{C_{f_i}} = \left\{\int_0^1 \left(\frac{T_e}{T}\right)^{1/2} d\left(\frac{U}{U_e}\right)\right\}^2 \tag{58}$$

The Stanton number was determined from the relation

$$S_t = 0.35\, C_{f_c} \tag{59}$$

which is supported by the experimental data of Back and Cuffel[21] for accelerating flows.

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21. Back, L.H. and Cuffel, R.F., "Relationship Between Temperature and Velocity Profiles in a Turbulent Boundary Layer along a Supersonic Nozzle with Heat Transfer," AIAA J. 8, 2066-2069 (1970).

Wall shear stress and heat transfer are then calculated from

$$\tau_w = \frac{1}{2} \rho_e U^2_e C_{f_c} \tag{60}$$

$$\dot{q}_w = -S_t \rho_e U_e C_p (T_{t_e} - T_w) \tag{61}$$

In order to obtain the velocity profiles the friction velocity profile, $(U/U_\tau)_i = f(U/U_e)$ is first determined from another Van Driest transformation,[7]

$$\left(\frac{U}{U_\tau}\right)_i = \left(\frac{2}{C_{f_c}}\right)^{1/2} \int_0^{U/U_e} \left(\frac{T_e}{T}\right)^{1/2} d\left(\frac{U}{U_e}\right) \tag{62}$$

where the friction velocity is defined as,

$$U_{\tau_i} = \left(\rho_e U_e^2 C_{f_i}/2\rho_w\right)^{1/2} \tag{63}$$

$(y/\delta)_i$ is then obtained from the standard incompressible boundary layer profiles[22] †

$$\frac{yU_\tau}{\nu} = \frac{U}{U_\tau}; \qquad \frac{U}{U_\tau} < 5 \tag{64}$$

$$\frac{yU_\tau}{\nu} = \exp\left\{\frac{U/U_\tau + 3.05}{2.5}\right\}; \quad 5 \le \frac{U}{U_\tau} \le 13.96 \tag{65}$$

$$\frac{yU_\tau}{\nu} = \exp\left\{\frac{U/U_\tau - 5.05}{2.5}\right\}; \quad \frac{U}{U_\tau} > 13.96 \tag{66}$$

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† The values of yU_τ/ν are normalized by $\exp\{[U/U_{\tau\,max} - 5.05]/2.5\}$ to avoid the calculation of the ν profile in the boundary layer.

22. Kays, W.M., Convective Heat and Mass Transfer (McGraw-Hill, New York, 1966).

Another Van Driest transformation yields $(y/\delta)_c = (y/\delta)_i$. Once the compressible profiles are known, Θ/δ, δ^*/δ, and the shape factor are determined from

$$\Theta/\delta = \int_0^1 \left(\frac{U}{U_e} \right)\left(1 - \frac{U}{U_e}\right) d\left(\frac{y}{\delta}\right) \tag{67}$$

$$\delta^*/\delta = \int_0^1 \left(1 - \frac{U}{U_e}\right) d\left(\frac{y}{\delta}\right) \tag{68}$$

$$H_{12} = \frac{\delta^*/\delta}{\Theta/\delta} \tag{69}$$

The variation of momentum thickness along the nozzle is determined via integration of the momentum integral equation,

$$\frac{C_{f_c}}{2} = \frac{d\Theta}{dx} + [H_{12} + 2]\Theta \frac{1}{U_e} \frac{dU_e}{dx} + \frac{\Theta}{\rho_e} \frac{d\rho_e}{dx} + \frac{\Theta}{R} \frac{dR}{dx} \tag{70}$$

by the use of backward differences.† δ and δ^* are then evaluated from Eqs. (67) and (68).

III. PREPARATION OF INPUT DATA

All necessary information for preparing input data is given below; Fig. 2 defines some of the input for a sample case. Many of the input parameters that are left blank are used in the companion rocket plume code[10] (AIPP), but not in FULLNOZ.

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† This requires that a throat value of 0 be assumed.

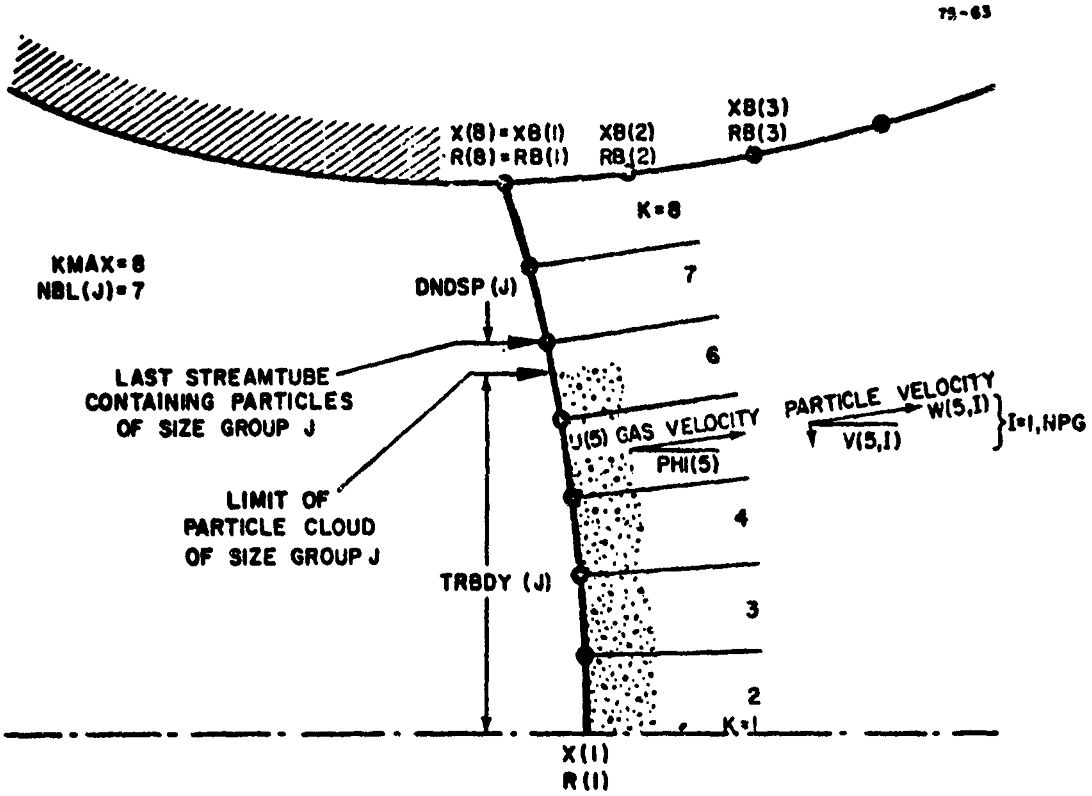

Figure 2. Input data definitions.

Card No.	Cols.	Fortran Name	Description	Format
1	1-10	NDATA	Number of data sets; in present version of code data sets cannot be stacked; therefore NDATA = 1	I.10
2	1-80	ID	Run identification	20A4
3	1-10	NSEC	Maximum run time (sec); when run time reaches NSEC nozzle properties at last orthogonal surface are punched and can be used to continue the calculation. (Not operational in present version of code)	I.10
	11-22	DXLSS	Approximate distance (cm) along axis between orthogonal surface print stations. For control of print increment by number of integration steps (KP, Card 5, Cols. 11-15) instead of axial distance, make DXLSS larger than XLMAX (below)	E12.5

Card No.	Cols.	Fortran Name	Description	Format
3	23-34	XLMAX	Maximum distance (cm) along axis for which calculations will be made. XLMAX should be set somewhat larger than axial distance to nozzle exit plane in order to complete calculation at last wall point	E12.5
4	1- 5	ITYPE	Inner boundary condition (nozzle axis) Set ITYPE = 1	I5
	6-10	IKIND	Outer boundary condition; set IKIND = 1 for wall boundary condition	
	11-15		Not used; leave blank	
	16-20		Not used; leave blank	
	21-25		Not used; leave blank	
	26-30	IBUGSH	Debug printout index; 0 - No debug printout 1 - Extensive printout for debugging	I5
	31-35		Not used; leave blank	
	36-40		Not used; leave blank	
	41-45		Not used; leave blank	
	46-50	IPART	Particle indicator; 0 - No particles 1 - Particles in flow	I5
	51-55		Not used; leave blank	
	56-60	ITURB	Turbulent flow indicator; 0 - Inviscid 3 - Constant values of turbulent mixing parameters, μ, Pr and Le are input on Card 10	I5
5	1- 5	KMAX	Initial number of streamtubes plus one (axis is counted as K = 1; maximum is 40)	I5
	6-10	NN	Number of terms for C_p polynomial curve fit plus one; for curve fits supplied with program,[12] NN = 6. If fewer coefficients are used for a given species NN is left at 6 and zeroes are input for the missing coefficients (see Card 8)	

Card No.	Cols.	Fortran Name	Description	Format
5	11-15	KP	Output control; number of orthogonal surfaces between print stations. To control print via axial distance (DXLSS, Card 3, Cols. 11-22) instead of orthogonal surfaces set KP larger than LPLANE (Card 5, Cols. 36-40)	
	16-20	MMAX	Number of points needed to describe shape of inner boundary; always set equal to 2 for axis boundary	I5
	21-25	NMAX	Number of points required to define nozzle wall contour (50 maximum)	I5
	26-30	NDS	Total number of gas species in flow (25 maximum)	I5
	31-35	NITER	Maximum number of iterations allowed for iterative solutions (e.g. calculation of streamtube properties for variable γ) Recommended value: NITER = 50	I5
	36-40	LPLANE	Maximum number of integration steps for entire calculation	I5
	41-45	IKINE	Number of chemical reactions (40 maximum)	I5

NOTE: IF NO BOUNDARY LAYER CALCULATIONS ARE TO BE MADE CARD 6 MAY BE LEFT BLANK, BUT MUST BE INCLUDED

Card No.	Cols.	Fortran Name	Description	Format
6	1- 5	TWALL	Nozzle wall temperature (^{o}K) (assumed constant)	F5.0
	8	IBLFLG	Boundary layer property printout indicator; 0 - Print Re, δ_1, θ_i, C_{f_i}, U_T, δ_c, δ_c^*, θ_c, C_{f_c}/C_{f_i}, H_{12}, q_w, T_w 1 - Print above plus velocity and temperature profiles	I1

Card No.	Cols.	Fortran Name	Description	Format
6	11	IBL	Boundary layer calculation indicator; 0 - Do not calculate boundary layer 1 - Calculate boundary layer	I1
7	1- 9	ALPHAH	Factor that multiplies maximum stable step size (see Eq. (28)); Recommended value: ALPHAH = 0.8	F9.4
	10-18	EPSLON	Amount by which streamtube Mach numbers must exceed one in order for the calculation to continue. Recommended value: EPSLON = 0.01	F9.4
	19-27	TOL	Convergence tolerance for iterative solutions; Recommended value: TOL = 1×10^{-4}	F9.4
	28-36	DELTA	Metric exponent†; 0 - Two-dimensional flow 1 - Axially symmetric flow	F9.4
	37-45	ATOL	Maximum allowable fractional change in streamtube area per step. Recommended value: ATOL = 0.1	F9.4

NOTE: CARD GROUP 8 DEFINES THE THERMODYNAMIC DATA FOR EACH SPECIES. THERE ARE 2 CARDS PER SPECIES AND NDS SPECIES

Card No.	Cols.	Fortran Name		Description	Format
8.1.1	1-13	A(1)	L_1	Specific heat polynomial constants for first species, see Section II.C.1 (cal/mole $^{\circ}$K)	E13.5
	14-26	A(2)	L_2		
	27-39	A(3)	L_3		
	40-52	A(4)	L_4		

† The particle conservation equations are written only for axially symmetric flow. Thus two-dimensional solutions can only be obtained for flows without particles.

Card No.	Cols.	Fortran Name	Description	Format
8.1.2	1-13	A(5)	L_5, Specific heat polynomial constant for first species	E13.5
	14-26	A(6)	L_6, Enthalpy constant of integration for first species $\left(\Delta H_f^o - \int_0^{298} C_p \, dT \right)$ (kcal/mole)	E13.5
	27-39	CS(1)	L_7, entropy constant of integration for first species (cal/mole ^oK)	
⋮				
8. NDS. 1 8. NDS.2			Repeat thermodynamic data for NDS species	

NOTE: CARD GROUP 9 IDENTIFIES EACH SPECIES AND SPECIFIES VARIOUS TRANSPORT PROPERTIES. MUST BE IN SAME ORDER AS CARD GROUP 8

Card No.	Cols.	Fortran Name	Description	Format
9.1	1- 4	IDENT(1)	Species name; first species (the remaining data on Card 9.1 also apply to the first species)	A4
	13-24	MUO(1)	Viscosity at reference temperature† (g/cm-sec); only used when flow contains particles. FOR IPART = 0, MUO MUST = 0 FOR ALL SPECIES	E12.4
	25-36	TO(1)	Reference temperature for viscosity (^oK)	E12.4
	37-48	OMEGA(1)	Exponent describing viscosity/temperature relation; $\mu \propto T^{\omega}$	E12.4
	49-60	PR(1)	Reciprocal of species Prandtl number	E12.4
	61-72	SC(1)	Reciprocal of species Schmidt number	E12.4
	73-80	MW(1)	Species molecular weight	E8.2
⋮				

† Values for common gases can be found in most physics and chemistry handbooks.

Card No.	Cols.	Fortran Name	Description	Format
9.NDS			Repeat for each species	
	NOTE:	CARD 10 IS NOT NEEDED IF ITURB = 0 (CARD 4, COLS. 56-60)		
10	1-10	TLE	Turbulent Lewis number (constant)	
	11-20	TPR	Turbulent Prandtl number (constant)	
	21-30	EDDYK	Eddy viscosity, g/cm-sec (constant)	
	NOTE:	CARD GROUPS 11 AND 12 DEFINE THE LOCATION OF THE INITIAL ORTHOGONAL SURFACE, AND THE FLOW ANGLE, PRESSURE, TEMPERATURE, VELOCITY AND SPECIES MASS FRACTIONS WITHIN EACH STREAMTUBE		
11	1-12	X(1)	Initial axial position on inner boundary (cm)	E12.4
	13-24	R(1)	Initial radial position on inner boundary (cm); usually equal to 0 for axis boundary	E12.4
	25-36	PHI(1)	Initial flow angle† on inner boundary (radians); usually equal to 0 for axis boundary	E12.4
12.1.1	1-12	X(2)	Axial position at outer boundary of first streamtube (cm)	E12.4
	13-24	R(2)	Radial position at outer boundary of first streamtube (cm)	E12.4
	25-36	PHI(2)	Flow angle at outer boundary of first streamtube (radians)	E12.4
	37-48	P(2)	Average pressure in first streamtube (atm)	E12.4
	49-60	T(2)	Average temperature in first streamtube ($^{\circ}$K)	E12.4
	61-72	U(2)	Average velocity in first streamtube (cm/sec)	E12.4
12.1.2	1-10	C(1,2)	Average mass fraction of first species in first streamtube	E10.3

† Flow angle is defined as the angle between the flow velocity vector and the axis.

Card No.	Cols.	Fortran Name	Description	Format
12.1.2	11-20	C(2,2)	Average mass fraction of second species in first streamtube	E10.3
	⋮		⋮	⋮
	71-80	C(8,2)	Average mass fraction of eighth species in first streamtube	E10.3
⋮				
12.1.I$(\frac{NDS}{8})$				

NOTE: I$(\frac{NDS}{8})$ DENOTES THE NEXT INTEGER LARGER THAN $(\frac{NDS}{8})$. REPEAT CARD 12.1.2 TO INCLUDE NDS SPECIES, 8 SPECIES/CARD

Card No.	Cols.	Fortran Name	Description	Format
12.2.1	1-12	X(3)	Axial position at outer boundary of second streamtube (cm)	E12.4
	⋮		⋮	
	61-72	U(3)	Average velocity in second streamtube (cm/sec)	E12.4
12.2.2	1-10	C(1,3)		E10.3
	⋮			⋮
	71-80	C(8,3)		⋮
⋮				⋮
12.2.I$(\frac{NDS}{8})$		C(NDS, 3)	Average mass fraction of last species in second streamtube	E10.3
⋮				
12.(KMAX-1).1	1-12	X(KMAX)	Axial position at outer boundary of last (KMAX-1) streamtube (cm)	E12.4
⋮				
12.(KMAX-1).I$(\frac{NDS}{8})$		C(NDS, KMAX)	Average mass fraction of last species in last streamtube	E10.3

NOTE: CARD 13 DEFINES THE POSITION OF THE INNER BOUNDARY

Card No.	Cols.	Fortran Name	Description	Format
13.1	1-12	XW(1)	Initial axial position (cm); repeat of X(1) on Card 10	E12.4
	13-24	RW(1)	Initial radial position (cm); repeat of R(1) on Card 10	E12.4

Card No.	Cols.	Fortran Name	Description	Format
13.1	25-36	PHIW(1)	Leave rest of card blank; program	E12.4
	37-48	PW(1)	will determine these inner boundary	E12.4
	49-60	SW(1)	properties	E12.4
13.2	1-12	XW(2)	Axial distance greater than XLMAX (Card 3, Cols. 23-34)(cm). Since the inner boundary is an axis the program will interpolate linearly between XW(1) and XW(2) to get axial locations of orthogonal surfaces. Therefore, set XW(2) = 1×10^{10}	E12.4
	13-24	RW(2)	Final radial position of inner boundary (cm); since inner boundary is an axis set RW(2) equal to R(1) on Card 11	E12.4
	25-36	PHIW(2)	Leave rest of card blank; program	E12.4
	37-48	PW(2)	will determine these inner boundary	E12.4
	49-60	SW(2)	properties	E12.4

NOTE: CARD GROUP 14 DEFINES THE POSITION OF THE OUTER BOUNDARY (NOZZLE WALL CONTOUR)

Card No.	Cols.	Fortran Name	Description	Format
14.1	1-12	XB(1)	Initial axial position of nozzle wall (cm); equal to X(KMAX) on Card 12.(KMAX-1).1	E12.4
	13-24	RB(1)	Initial radial position of nozzle wall (cm); equal to R,KMAX) on Card 12.(KMAX-1).1	E12.4
14.2	1-12	XB(2)	Axial position (cm) of second point along nozzle wall	E12.4
	13-24	RB(2)	Radial position (cm) of second point along nozzle wall	E12.4
•				
•				
14.NMAX	1-12	XB(NMAX)	Final axial position (cm) of nozzle wall	E12.4
	13-24	RB(NMAX)	Final radial position (cm) of nozzle wall	E12.4

NOTE: CARD GROUPS 15-19 AND 20-24 (OR 25-32) ARE INCLUDED ONLY IF PARTICLES ARE IN FLOW, i.e. IPART = 1 (CARD 4, COLS. 46-50)

Card No.	Cols.	Fortran Name	Description	Format
15	1-10	FFF	Factor which multiplies particle/gas drag coefficient (see Section II.C.3)	E10.3

Card No.	Cols.	Fortran Name	Description	Format
15.	11-20	FFG	Factor which multiplies particle/gas heat transfer coefficient (see Section II.C.3)	E10.3
	21-30	CL	Liquid particle specific heat (cal/g-°K)	E10.3
	31-40	CS	Solid particle specific heat (cal/g-°K)	E10.3
	41-50	HTRAN	Particle heat of solidification (cal/g)	E10.3
	51-60	WT	Particle molecular weight	E10.3
16	1-10	RHSS	Particle density (g/cm^3)	E10.3
	11-20		Not used; leave blank	
	21-30		Not used; leave blank	
	31-40	TPS	Particle solidification temperature (°K)	E10.3
17	1- 5	NPG	Number of particle groups (8 maximum)	I5
	6-10	NC	Index noting whether particle properties are constant or variable along initial orthogonal surface 0 - constant 1 - variable	I5

NOTE: NBL( ) INDICATES RADIAL EXTENT OF EACH PARTICLE GROUP ALONG INITIAL ORTHOGONAL SURFACE (SEE FIG. 2); DEFINED AS LAST STREAMTUBE NUMBER CONTAINING PARTICLES PLUS 2. FOR EXAMPLE, IF THE FIRST PARTICLE GROUP EXTENDS TO STREAMTUBE NO. 12, NBL(1) = 14

Card No.	Cols.	Fortran Name	Description	Format
18	1- 5	NBL(1)	Last streamtube containing first particle group along initial orthogonal surface (streamtube number + 2)	I5
	•			
	•			
		NBL(NPG)	Last streamtube containing NPG particle group (streamtube number + 2)	I5
19	1-10	RP(1)	Radius of first particle group (cm)	8E10.3
	•	•		
	•	•		
		RP(NPG)	Radius of NPG particle group (cm)	

Card No.	Cols.	Fortran Name	Description	Format
	NOTE:	IF PARTICLE PROPERTIES ALONG INITIAL ORTHOGONAL SURFACE ARE CONSTANT (NC = 0) CARDS 20-24 ARE INPUT; IF NC = 1 THE NEXT CARD GROUP IS NO. 25		
20	1-10	WI(1)	Velocity of first particle group in streamline direction (cm/sec)	E10.3
	11-20	WI(2)	Velocity of second particle group in streamline direction (cm/sec)	E10.3
	•	•		•
	•	•	•	•
		WI(NPG)	Velocity of NPG particle group in streamline direction (cm/sec)	E10.3
21	1-10	VI(1)	Velocity of first particle group normal to streamline (cm/sec)	E10.3
	11-20	VI(2)	Velocity of second particle group normal to streamline (cm/sec)	E10.3
	•	•		•
	•	•	•	•
		VI(NPG)	Velocity of NPG particle group normal to streamline (cm/sec)	E10.3
22	1-10	TPI(1)	Temperature of first particle group (°K)	E10.3
	11-20	TPI(2)	Temperature of second particle group (°K)	E10.3
	•	•	•	•
	•	•	•	•
		TPI(NPG)	Temperature of NPG particle group (°K)	E10.3
23	1-10	RHP(1)	Particle cloud density of second particle group (g/cm^3)	E10.3
	11-20	RHPI(2)	Particle cloud density of second particle group (g/cm^3)	E10.3
	•	•		•
	•	•	•	•
		RHPI(NPG)	Particle cloud density of NPG particle group (g/cm^3)	E10.3

Card No.	Cols.	Fortran Name	Description	Format
	NOTE:	IF A PARTICLE GROUP IS AT THE SOLIDIFICATION TEMPERATURE THE AMOUNT OF HEAT WHICH HAS BEEN TRANSFERRED FROM THE LIQUID PARTICLES (i.e. SOME FRACTION OF THE TOTAL HEAT OF SOLIDIFICATION) IS INPUT ON CARD 24. IF THE PARTICLE TEMPERATURE IS ABOVE OR BELOW THE SOLIDIFICATION TEMPERATURE, DENGI(J) = 0 (J = 1, NPG)		
24	1-10	DENGI(1)	Heat transferred from first particle group at solidification temperature (cal)	E10.3
	11-20	DENGI(2)	Heat transferred from second particle group at solidification temperature (cal)	E10.3
	•	•	•	•
	•	•	•	•
		DENGI(NPG)	Heat transferred from NPG particle group at solidification temperature (cal)	E10.3
	NOTE:	IF PARTICLE PROPERTIES ALONG INITIAL ORTHOGONAL SURFACE ARE VARIABLE (NC = 1) CARDS 25-32 ARE INPUT (SEE FIG. 2)		
25.1	1-10	W(1,1)	Streamwise velocity of first particle group at r = 0 (cm/sec)	E10.3
	11-20	W(1,2)	Streamwise velocity of second particle group at r = 0 (cm/sec)	E10.3
	•	•	•	•
	•	•	•	•
		W(1,NPG)	Streamwise velocity of NPG particle group at r = 0 (cm/sec)	E10.3
26.1	1-10	V(1,1)	Normal velocity of first particle group at r = 0 (cm/sec); generally = 0	E10.3
	11-20	V(1,2)	Normal velocity of second particle group at r = 0 (cm/sec); generally = 0	E10.3
	•	•	•	•
	•	•	•	•
	•	•	•	•
		V(1,NPG)	Normal velocity of NPG particle group at r = 0 (cm/sec); generally = 0	E10.3

Card No.	Cols.	Fortran Name	Description	Format
27.1	1-10	TP(1,1)	Temperature of first particle group at r = 0 (°K)	E10.3
	11-20	TP(1,2)	Temperature of second particle group at r = 0 (°K)	E10.3
	•	•		
	•	•		
		TP(1,NPG)	Temperature of NPG particle group at r = 0 (°K)	E10.3
28.1	1-10	RHP(1,1)	Particle cloud density of first particle group at r = 0 (g/cm^3)	E10.3
	11-20	RHP(1,2)	Particle cloud density of second particle group at r = 0 (g/cm^3)	E10.3
	•	•		•
	•	•		•
		RHP(1,NPG)	Particle cloud density of NPG particle group at r = 0 (g/cm^3)	E10.3
29.1	1-5	ICOND(1,1)	Index which indicates whether first particle group is at solidification temperature at r = 0 ICOND = 0; No = 1; Yes	I5
	6-10	ICOND(1,2)	Same as above for second particle group	I5
	•	•	•	
	•	•	•	
		ICOND(1,NPG)	Same as above for NPG particle group	I5
30.1	1-10	DENG(1,1)	Heat transferred from first particle group at r = 0 at solidification temperature (cal) (See NOTE on page)	E10.3
	11-20	DENG(1,2)	Same as above for second particle group	E10.3
	•	•	•	
	•	•	•	
		DENG(1,NPG)	Same as above for NPG particle group	E10.3
25.2 26.2 27.2 28.2 29.2 30.2			Same as 25.1, 26.1, 27.1, 28.1, 29.1, and 30.1, except for first streamtube • •	

Card No.	Cols.	Fortran Name	Description	Format
25.(NBL-1)			•	
26.(NBL-1)			•	
27.(NBL-1)			Same as above except for last stream-tube containing particles	
28.(NBL-1)				
29.(NBL-1)				
30.(NBL-1)				

NOTE: CARDS 31 AND 32 LOCATE THE INITIAL BOUNDARY OF EACH PARTICLE GROUP

Card No.	Cols.	Fortran Name	Description	Format
31	1-10	TRBDY(1)	Distance from axis, along initial orthogonal surface, to boundary of first particle group (cm) (see Fig. 2)	E10.3
	11-20	TRBDY(2)	Same as above for second particle group	E10.3
	•	•		•
	•	•		•
		TRBDY(NPG)	Same as above for NPG particle group	E10.3
32	1-10	DNDSP(1)	Distance from outer boundary of last streamtube containing particle to boundary of first particle group at initial orthogonal surface (cm) (see Fig. 2)	E10.3
	11-20	DNDSP(2)	Same as above for boundary of second particle group	E10.3
	•	•	•	•
	•	•	•	•
		DNDSP(NPG)	Same as above for boundary of NPG particle group	

NOTE: THE FOLLOWING CARDS CONTAIN THE REACTION MECHANISM AND RATE COEFFICIENTS. USE ONLY IF IKINE (CARD 5, COLS. 41-45) IS GREATER THAN 0. (SEE SECTION II.C.2 FOR REACTION AND RATE COEFFICIENT TYPES)

Card No.	Cols.	Fortran Name	Description	Format
33.1	1- 4	IZD(1)	Species A	A4
	7		+ sign	
	8-11	IZD(2)	Species B	A4
	14		+ sign	
	15-20		Blank or M	A4

Card No.	Cols.	Fortran Name	Description	Format
33.1	21		= sign	
	22-25	IZD(3)	Species C	A4
	28		+ sign (if needed)	
	29-32	IZD(4)	Species D	A4
	35		+ sign (if needed)	
	36-39	IZD(5)	Species E	A4
	49-50	IRR	Reaction type (1 to 10)	I2
	51	IRT	Rate coefficient type (1 to 8)	I1
	52-59	RC(1)	Pre-exponential factor, A (cm-molecule-sec units)	E8.2
	60-63	RC(2)	Temperature exponent, N	F4.1
•	64-72	RC(3)	Activation energy, B (cal/mole)	F9.1
•				
•				
33.IKINE			Same as above for IKINE reaction	

IV. PRELIMINARY RESULTS

This section gives the results of several sample calculations made with FULLNOZ and an analysis performed to determine heterogeneous electron-ion recombination rates in solid propellant nozzle flows.

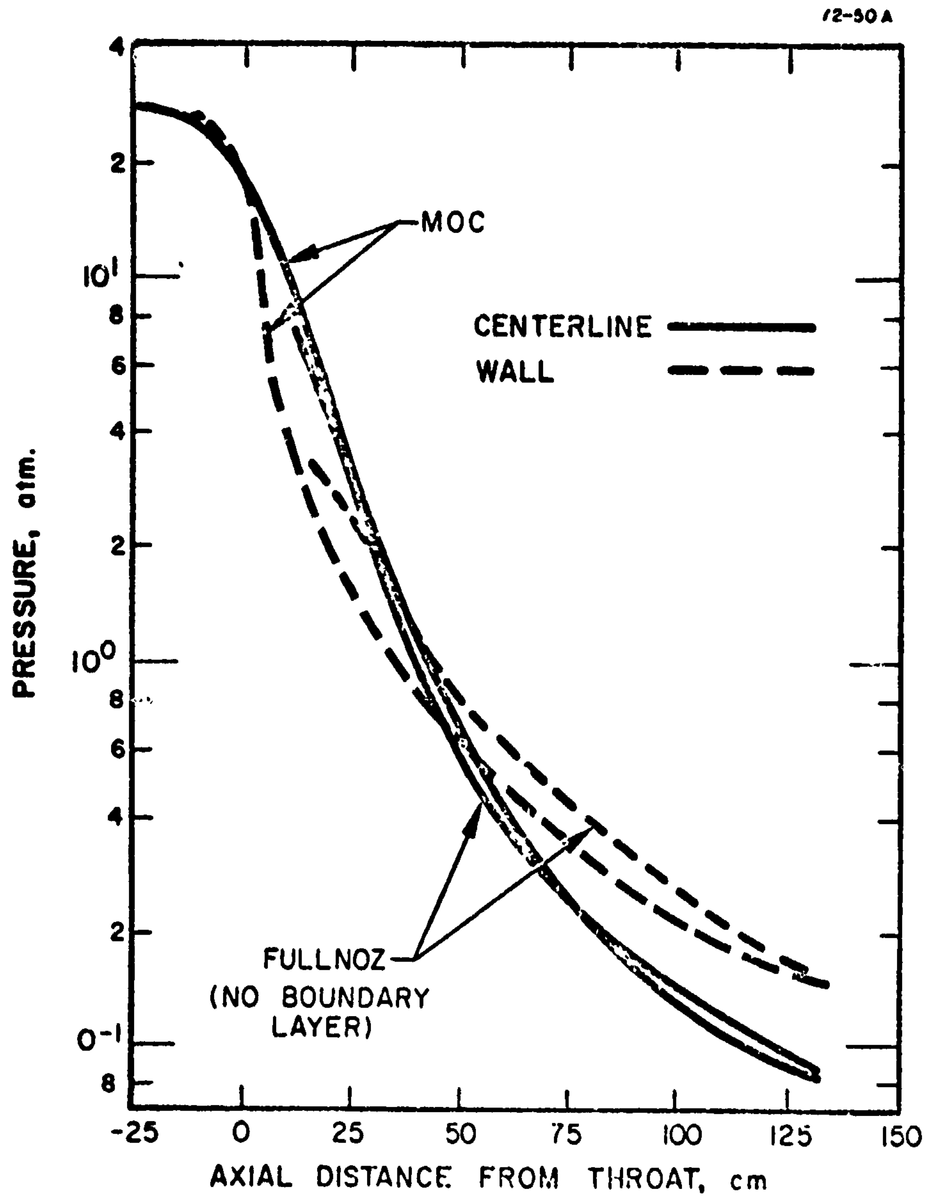

Figure 3. Comparison between Method of Characteristics (MOC) and FULLNOZ calculations of MM-Stage 2 nozzle pressure distributions.

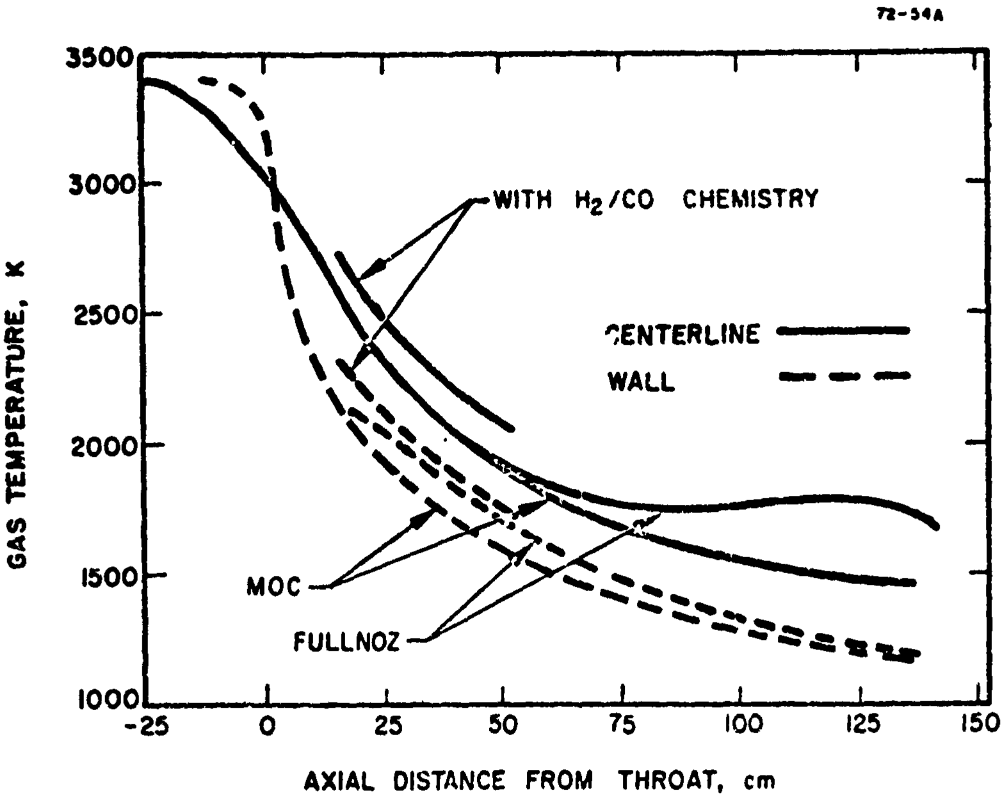

Figure 4. Comparison between Method of Characteristics (MOC) and FULLNOZ calculations of MM-Stage 2 nozzle gas temperature distributions.

A. Sample Calculations

Initial calculations with FULLNOZ were compared with calculations for the Minuteman, Stage 2 nozzle using a two-phase constant γ method of characteristics (MOC) code.[3] The purpose of this comparison was to check the numerical accuracy of the code. Input data for the calculations are given in Ref. 23.

Figures 3 and 4 show the pressure and temperature distributions along the centerline and wall (with no boundary layer effects). The pressure distributions compare very well, but FULLNOZ temperatures are slightly higher than those calculated via the MOC code. The centerline gas temperature calculated with FULLNOZ shows a more pronounced effect of gas/parti-

23. Pergament, H.S. and Mikatarian, R.R., "Predictions of Minuteman Exhaust Plume Electrical Properties," AeroChem TP-281, July 1972.

cle interactions than was demonstrated by the MOC code. The results of a short run with FULLNOZ, including a set of 10 reactions involving H_2/CO chemistry, (see Ref. 23 for the reaction mechanism and rate coefficients) are also shown on Fig. 4.

Figures 5 and 6 show the influence of boundary layer heat transfer and shear stress on the temperature and velocity within the wall streamtube. The largest effects are observed for the cold (500°K) wall; when the wall is near the adiabatic wall temperature (≈ 3000°K) the results are similar to those for no boundary layer.

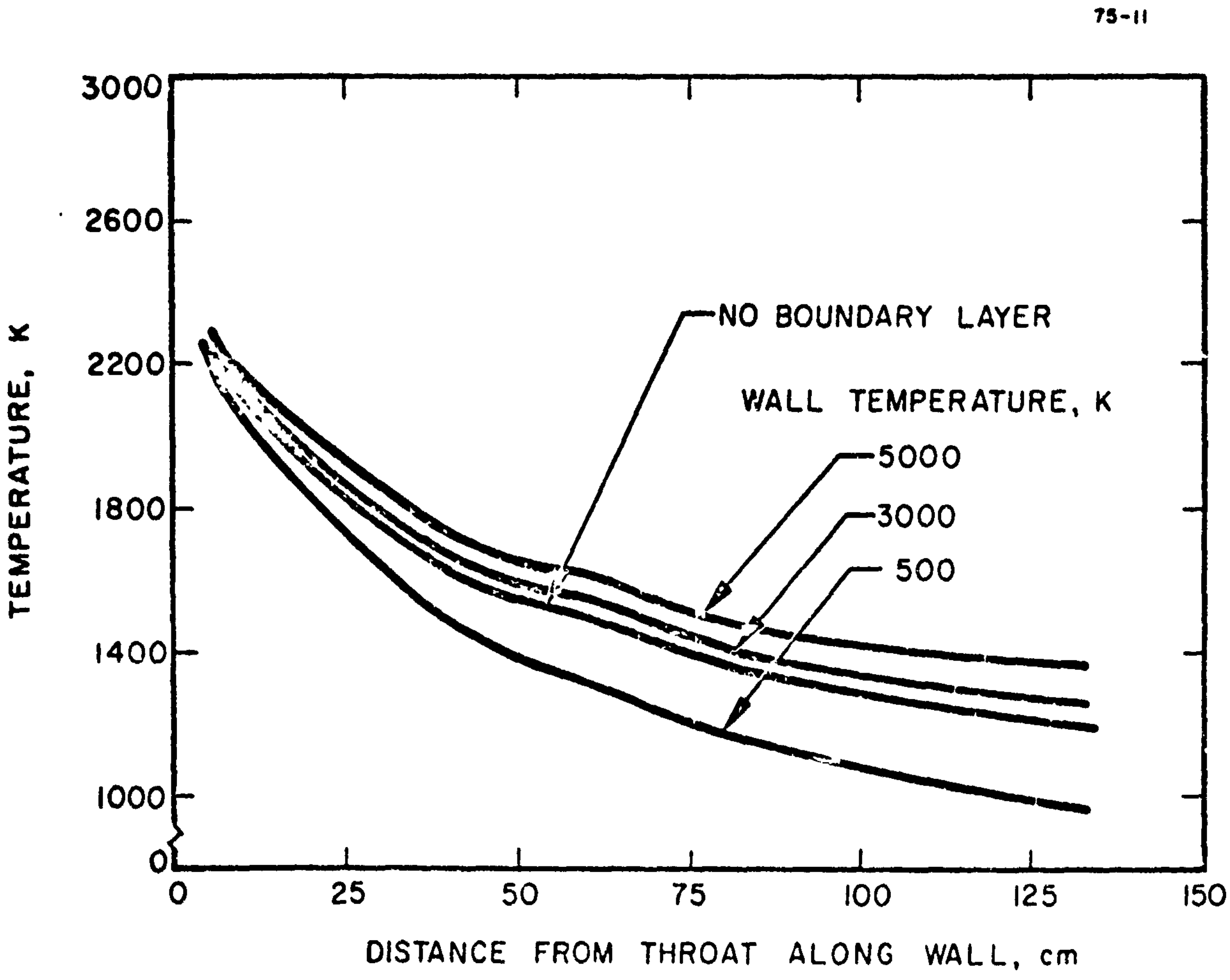

Figure 5. Influence of nozzle boundary layer on wall streamtube temperature.

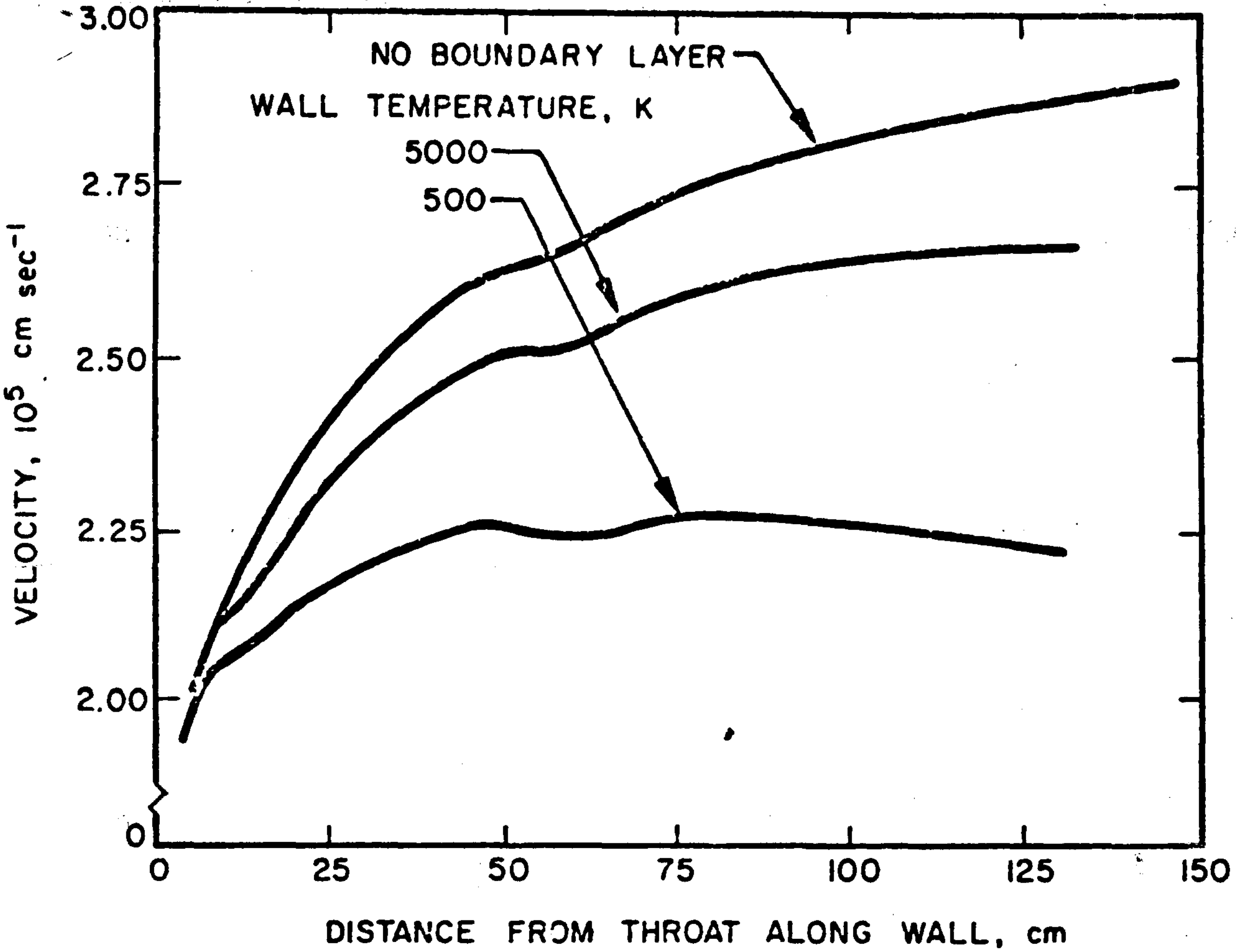

Figure 6. Influence of nozzle boundary layer on wall streamtube velocity.

Figure 7 shows the boundary layer velocity and temperature profile at the nozzle exit plane; Table 1 demonstrates that the boundary layer displacement and momentum thicknesses are much less than the wall streamtube thickness, i.e. all boundary layer effects are confined to the wall streamtube.

Figures 8 and 9 show the results of a parametric series of calculations in which the gas/particle drag and heat transfer coefficients were arbitrarily varied (via the factors FFF and FFG on Card 15) over their approximate ranges of uncertainty to test the effect on exit plane and particle properties. Figure 8 shows that varying FFF and FFG can have significant effects on gas temperatures and velocities. Figure 9 demonstrates that the 4μ diameter particles can be either at the solidification temperature or completely solidified, depending on the value chosen for FFG.

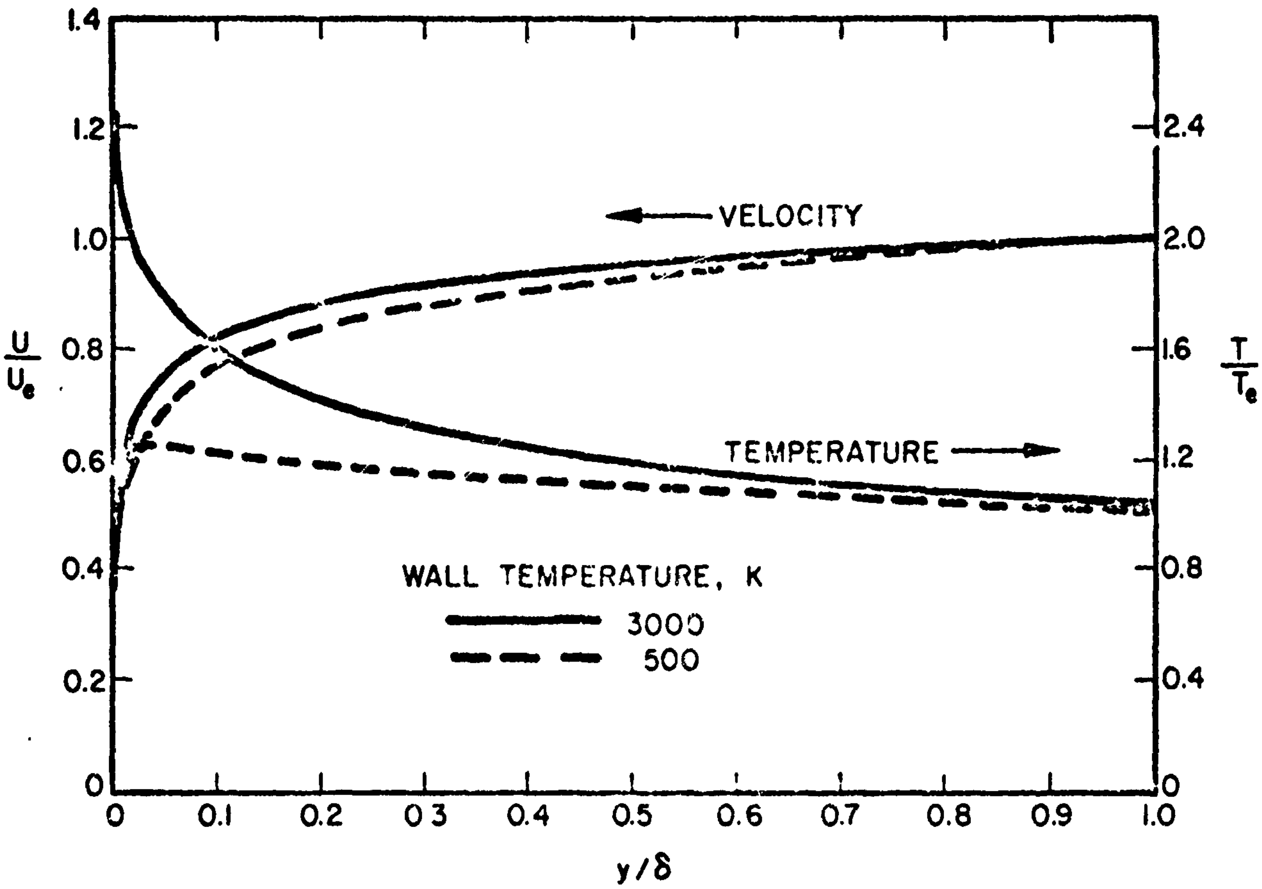

Figure 7. Boundary layer profiles at MM-Stage 2 nozzle exit plane.

TABLE 1

NOZZLE EXIT PLANE BOUNDARY LAYER PARAMETERS

MM-Stage 2 (Ref. 23)

Nozzle Exit Radius = 60.9 cm
Axial Distance From Throat = 134 cm

	Wall Temperature, °K	
	500	3000
Wall Streamtube Width, cm	1.24	1.38
Boundary Layer Thickness, cm	4.45	2.50
Displacement Thickness, cm	0.451	0.196
Momentum Thickness, cm	0.355	0.161

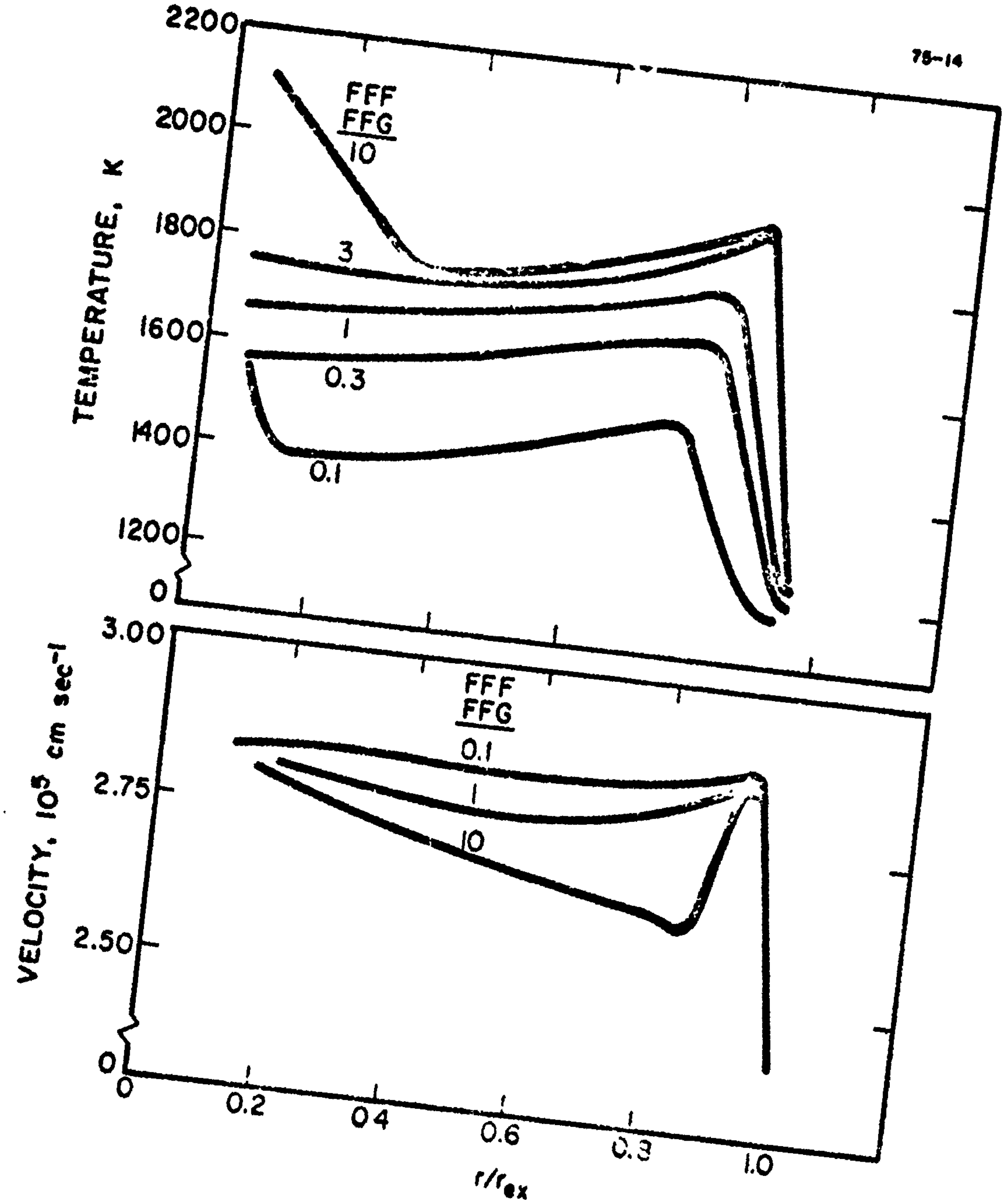

Figure 8. Influence of particle drag and heat transfer coefficients on exit plane gas properties.

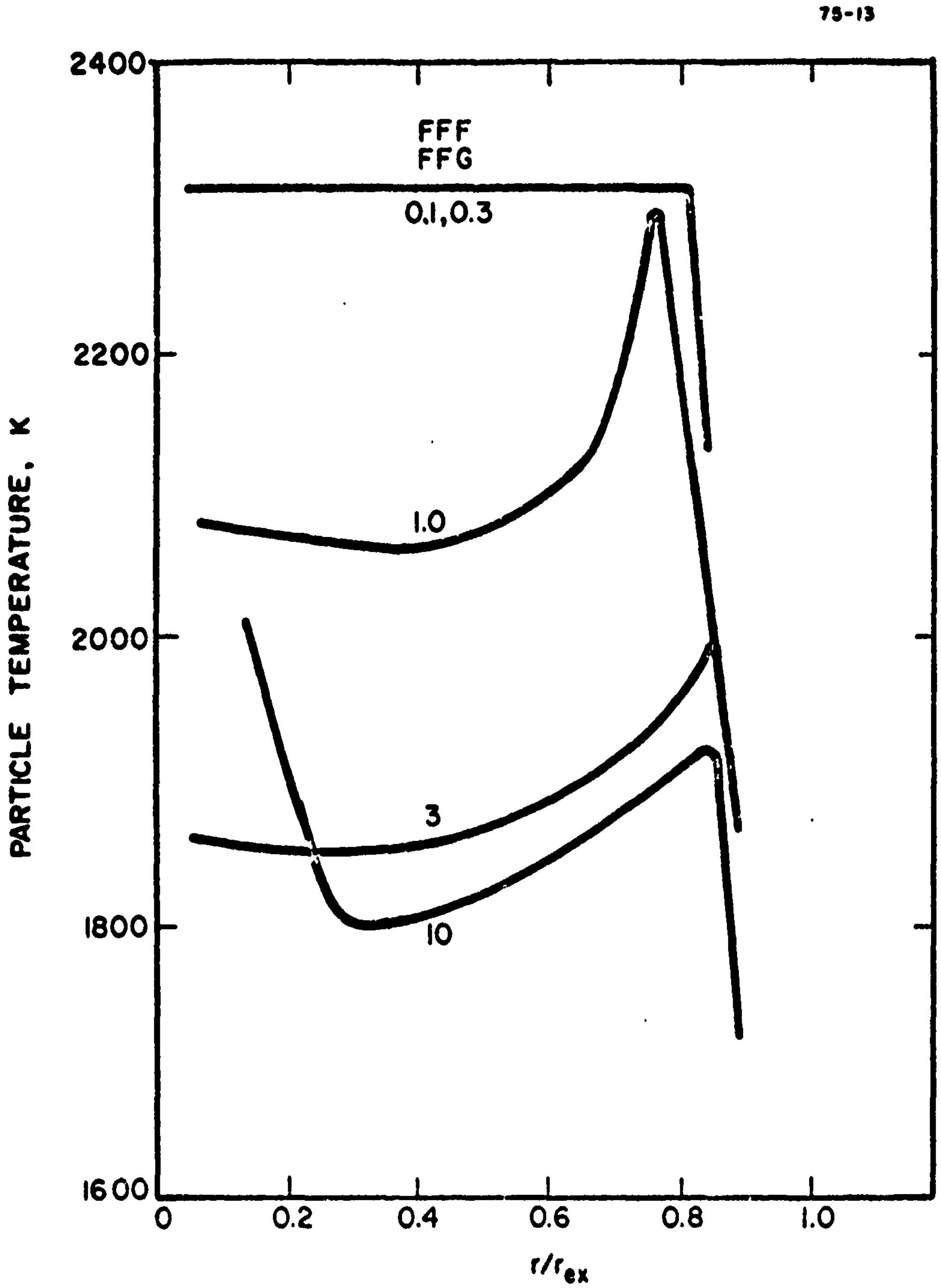

Figure 9. Influence of particle drag and heat transfer coefficients on exit plane particle temperatures.

B. Heterogeneous Electron Ion Recombination

One of the unanswered questions in determining nozzle exit plane electron mole fractions is the extent to which heterogeneous electron/ion recombination on the surface of solid particles can enhance homogeneous electron/ion recombination rates. Towards this end we have adopted a model developed at AeroChem by Calcote, Kurzius and Silla[24] in which a negatively charged particle (particles are negatively charged because the electrons will reach the surface more rapidly than positive ions) is neutralized by positive ions striking the surface. Thus, instead of requiring a three-body collision for recombination, only a two-body collision between the solid particle and positive ion need occur. To a first approximation the particle electron recombination rate can be equated to the rate at which positive ions strike the solid particles. However, if negative ions are present (for typical solid propellants mole fractions of Cl^- are from 2 to 3 orders of magnitude greater than electron mole fractions) the electron recombination rate will decrease, since some of the positive ions will react with negative ions rather than electrons.

The solid particle electron recombination coefficient, α_{p_e}, is defined from

$$\left(\frac{dn_e}{dt}\right)_p = -\alpha_{p_e} n_+ n_p \tag{71}$$

where n_e is electron density, t is time, n_+ is positive ion density and n_p is the particle number density. If particle diameters are small compared to the gas mean free path† (free molecular flow) and the electron densities are sufficiently high that the particles remain negatively charged, α_{p_e} is essentially the random ion flux to the particle (with a correction factor for negative ions),

$$\alpha_{p_e} = \pi r^2 \left(\frac{8kT}{\pi m_+}\right)^{1/2} \left[1 + \left(\frac{n_-}{n_e}\right)\left(\frac{m_e}{m_-}\right)^{1/2}\right]^{-1} \tag{72}$$

---

† If particle diameters are not small compared to the mean free path corrections will have to be made to the expression for α_{p_e}.

24. Calcote, H.F., Kurzius, S.C., and Silla, H., "Solid Propellant Flame Ionization and the Effect of Chemical Additives," Third Radar Attenuation Symposium, CPIA Publ. No. 46 (Applied Physics Lab., Johns Hopkins Univ., Silver Spring, 1964), pp. 17-40.

where r is the particle radius, k is the Boltzmann constant, T is the gas temperature, m_+, m_e, and m_- are the masses of positive ions, electrons and negative ions, respectively, and n_- is the negative ion density.

Equations (71) and (72) represent the formal method for incorporating heterogeneous electron/ion recombination into FULLNOZ. However, we must also account for the possibility that, at the high temperatures near the nozzle throat, the particle is emitting electrons via thermionic emission. Under these conditions a steady state is achieved by balancing the random current density to the particle (from the plasma) by thermionic emission. Equating these electron currents results in a "critical" electron density for which the net current flow to the particle is zero and an initially neutral particle will remain neutral. This critical electron density is defined by,

$$(n_e)_{cr} = B\left(\frac{T_p}{T_g}\right) T_g^{3/2} \exp\left[-11,605\, E_w/T_p\right] \tag{73}$$

where B is the thermionic emission constant, T_p is the particle temperature, T_g is the gas temperature and E_w is the effective work function of the particle in volts. Thus, heterogeneous electron/ion recombination is only of potential importance for $n_e > (n_e)_{cr}$.

The technique adopted to incorporate the above equations into FULLNOZ is:

1. At each integration step determine whether the local electron density is greater than the critical electron density. (During the initial stages of the expansion process, where particle temperatures are very high it is likely that $n_e < (n_e)_{cr}$.)

2. If $n_e < (n_e)_{cr}$ then electron/ion recombination will not be significant and Eqs. (71) and (72) will not be employed.

3. If $n_e > (n_e)_{cr}$ Eqs. (71) and (72) will be incorporated directly into the general kinetic scheme (with possible corrections to Eq. (72) due to non-free molecular flow effects).

The above procedure has not as yet been incorporated into the code.

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APPENDIX A

SAMPLE INPUT DATA

AeroChem

FULLNOZ


```
CARD
NO

1       1
2 *** FULLY COUPLED NUZZLE FLOW PROGRAM - FULLNOZ  -  SAMPLE TEST CASE 9/75 ***
3      7200      2.000E+2      1.524E+2
4    1     1                       0                  1              0
5    25    6    10    2    22    10    50    900    10
6 1000.   1   1
7        0.8      0.01     1.0E-4        1.0         0.1
811.64408562 E+1.18575287 E+1-.44865856E+0.36280951 E-1                CO 1
 2-.5981864 E-2-.28443584E+2.54410327 E+2                              CO 2

821.58741331E+1.13592404E+02 -.86056609E1  .21500497E+1                CO2 1
 2-.30567063E+1-.96439872E+2 .54321459E+2                              CO2 2

831.49683629 E+1-.23301268E-3.59667528 E-4-.51872545E-5                H 1
 2-.18467323E-4.50618655 E+2.33404654 E+2                              H 2

841.60596451 E+1.13412152 E+1-.16508752E+0.88760457 E-2                H2 1
 2.46616242 E-1-.17005029E+1.38413271 E+2                              H2 2

851.58818265 E+1.17395375 E+1-.32536218E+0.22313547 E-1                OH 1
 2.75177541 E-1.79212009 E+1.50938996 E+2                              OH 2

861.60311014 E+1.47049758 E+1-.96291245E+0.69087996 E-1                H2O 1
 2.60421152 E-1-.59593534E+2.51387265 E+2                               H2O 2
```

AeroChem

FULLNOZ


```
CARD
No

871.62643469 E+1.19328092 E+1-.46158274E+0.37083135 E-1                N2 1
 2.91852768 E-2-.19242408E+1.52824774 E+2                              N2 2

881.50617760 E+1-.11736656E+0.39405358 E-1-.20531577E-2                O 1
 2.18127099 E-1.58115304 E+2.44728172 E+2                              O 2

891.72417589 E+1.12398122 E+1-.18448469E+0.10507580 E-1                O2 1
 2-.59604067E-1-.24219968E+1.57031740 E+2                              O2 2

8101.48485464 E+1.32006164 E+0-.28545471E+0.83218696 E-1               K 1
 2.43725018 E-2.19867370 E+2.44106314 E+2                              K 2

91 CO          139.  E-6     300.     0.75      1.4      1.4     28.
 2 CO2         139.  E-6     300.     0.75      1.4      1.4     44.
 3 H           83.5 E-6      300.     0.75      1.4      1.4      1.
 4 H2          83.5 E-6      300      0.75      1.4      1.4      2.
 5 OH         125.5 E-6      300.     0.75      1.4      1.4     17.
 6 H2O        125.5 E-6      300.     0.75      1.4      1.4     18.
 7 N2          160.  E-6     300      0.75      1.4      1.4     28.
 8 O           166.  E-6     300.     0.75      1.4      1.4     16.
 9 O2          189.  E-6     300.     0.75      1.4      1.4     32.
10 K          129.7 E-6      300.     0.75      1.4      1.4     39.1
```

~NOTE~ CARD 10 OMITTED FOR ITURB=0(CARD 4, COL. 56-60)

AeroChem

FORTRAN Coding Form

FULLNOZ 3 14

FORTRAN STATEMENT

CARD No								
11	12.668	0.0	0.0					
12 1 1	12 663	0.6053	0.01804	8.500	2761.	1.534E+5		
.2	3.0E-1	6.0E-2	6.3E-4	2 4E-2	2 6E-3	1.9E-1	4.2E-1	7.8E-5
3	5.6E-5	1.1E-6						
12 2 1	12.646	1.2110	0.03607	8.473	2759.	1.534E+5		
.2	NOTE — CARDS 12.2.2 TO 12.24.2 ARE IDENTICAL TO CARD 12.1.2							
.3	CARDS 12.2.3 TO 12.24.3 ARE IDENTICAL TO CARD 12.1.3							
12.3 1	12.619	1.8158	0.05411	8.443	2758.	1.534E+5		
..2	SEE NOTE							
.3								
12.4 1	12.581	2.4199	0.07214	8.400	2757.	1.536E+5		
2	SEE NOTE							
3								
12 5 1	12.532	3 0238	0.09018	8.343	2755.	1.538E+5		
2	SEE NOTE							
3								
12.6 1	12.472	3.6262	0.10821	8.273	2751.	1.541E+5		
.2	SEE NOTE							
3								

AeroChem

FORTRAN Coding Form

FULLNOZ 4 14

FORTRAN STATEMENT

CARD NO						
12 7 1	12.401	4.2274	0.12625	8.193	2745.	1.5[illegible]5E+5
	SEE NOTE					
.3						
12 8 1	12.319	4.8278	0.14428	8.103	2739.	1.550E+5
2	SEE NOTE					
3						
12 9 1	12.227	5 4260	0.16232	8.003	2732.	1.556E+5
.2	SEE NOTE					
3						
12 10 1	12 123	6.0225	0.18035	7.895	2726.	1 562E+5
2	SEE NOTE					
3						
12 11 1	12.009	6.6176	0.19839	7.775	2719.	1.570E+5
2	SEE NOTE					
3						
12 12 1	11.885	7.2100	0.21642	7 643	2712.	1.578E+5
2	SEE NOTE					
3						

FORTRAN Coding Form

FULLNOZ 5 14

FORTRAN STATEMENT

CARD NO						
12131	11.749	7.8000	0.23446	7.498	2708.	1.588E+5
.2	SEE NOTE					
3						
12141	11.603	8.3880	0.25249	7.328	2700.	1.600E+5
2	SEE NOTE					
3						
12151	11.447	8.9728	0.27053	7.138	2688.	1.613E+5
.2	SEE NOTE					
.3						
12161	11.280	9.5546	0.28856	6.935	2671.	1.629E+5
.2	SEE NOTE					
3						
12171	11.102	10.1340	0.30660	6.715	2648.	1.647E+5
.2	SEE NOTE					
3						
12181	10.914	10.7090	0.32463	6.480	2624.	1.670E+5
.2	SEE NOTE					
.3						

FORTRAN Coding Form

FULLNOZ 6 14

CARD NO						
12191	10.716	11.2810	0.34267	6.225	2594.	1.676E+5
2	SEE NOTE					
3						
12201	10.507	11.8500	0.36070	5.950	2563.	1.725E+5
.2	SEE NOTE					
.3						
12211	10.289	12.4150	0.37874	5.680	2550.	1.761E+5
2	SEE NOTE					
3						
12221	10.060	12.9750	0.39677	5.390	2533.	1.798E+5
2	SEE NOTE					
3						
12231	9.8205	[illegible]	0.41481	5.065	2502.	1.847E+5
.2	SEE NOTE					
3						
12241	9.5715	14.0840	0.43284	4.602	2401.	1.904E+5
2	SEE NOTE					
3						

AeroChem FORTRAN Coding Form

FULLNOZ 7 14

CARD NO		
13.1	12.668	0.0
.2	1.0E+10	0.0
14.1	9.5715	14.084
.2	9.957	14.275
.3	10.312	14.503
.4	11.582	15.215
.5	12.852	15.850
.6	14.122	16.434
.7	16.662	17.729
.8	19.202	18.999
.9	21.742	20.218
.10	26.822	22.606
.11	31.902	24.994
.12	36.982	27.305
.13	44.602	30.683
.14	52.222	33.985
.15	59.842	37.084
.16	73.914	42.062
.17	87.173	46.838
.18	99.035	50.749
.19	111.150	54.508
.20	123.490	58.039
.21	134.420	60.909
.22	152.400	65.634

AeroChem FORTRAN Coding Form

FULLNOZ 8 14

CARD NO							
15.1	1.0	1.0	0.339	0.323	255.	102.	
16.1	4.0			2320.			
17.1	4	1					
18.1	19	19	19	19			
19.1	1.0E-4	2.0E-4	3.0E-4	4.0E-4			

NC (CARD 17, COL. 10) = 1, THEREFORE CARD NO 25 IS NEXT

CARD NO				
25.1	0.147 E+6	0.139 E+6	0.131 E+6	0.124 E+6
26.1	-0.276 E+3	-0.559 E+3	-0.768 E+3	-0.101 E+4
27.1	2813.	2893	2913.	2973.
28.1	0.279 E-4	0.143 E-3	0.182 E-3	0.554 E-4
29.1	0	0	0	0
30.1	0.0	0.0	0.0	0.0
25.2	0.147 E+6	0.139 E+6	0.132 E+6	0.125 E+6
26.2	-0.292 E+3	-0.592 E+3	-0.814 E+3	-0.107 E+4
27.2	2813.	2893.	2913.	2973.
28.2	0.279 E-4	0.143 E-3	0.182 E-3	0.554 E-4

29.2, 30.2 — NOTE — CARDS 29.2 TO 29.18 ARE IDENTICAL TO 29.1
CARDS 30.2 TO 30.18 ARE IDENTICAL TO 30.1

CARD NO				
25.3	0.148 E+6	0.139 E+6	0.132 E+6	0.125 E+6
26.3	-0.310 E+3	-0.629 E+3	-0.864 E+3	-0.114 E+4

FORTRAN Coding Form

FULLNOZ — 9 14

CARD NO								
27.3	2813.		2893.		2913.		2973.	
28.3	0.279	E-4	0.143	E-3	0.182	E-3	0.554	E-4
29.3								
30.3								
25.4	0.148	E+6	0.139	E+6	0.132	E+6	0.125	E+6
26.4	-0.331	E+3	-0.671	E+3	-0.922	E+3	-0.121	E+4
27.4	2813.		2893.		2913.		2973.	
28.4	0.279	E-4	0.143	E-3	0.182	E-3	0.554	E-4
29.4								
30.4								
25.5	0.148	E+6	0.140	E+6	0.132	E+6	0.125	E+6
26.5	-0.366	E+3	-0.719	E+3	-0.988	E+3	-0.130	E+4
27.5	2813.		2893.		2913.		2973.	
28.5	0.279	E-4	0.143	E-3	0.182	E-3	0.554	E-4
29.5								
30.5								
25.6	0.148	E+6	0.140	E+6	0.132	E+6	0.125	E+6
26.6	-0.382	E+3	-0.775	E+3	-0.106	E+4	-0.140	E+4
27.6	2813.		2893.		2913.		2973.	
28.6	0.279	E-4	0.143	E-3	0.182	E-3	0.554	E-4
29.6								

FORTRAN Coding Form

FULLNOZ — 10 14

CARD NO								
30.6								
25.7	0.149	E+6	0.140	E+6	0.132	E+6	0.125	E+6
26.7	-0.414	E+3	-0.839	E+3	-0.115	E+4	-0.151	E+4
27.7	2803.		2883.		2913.		2963.	
28.7	0.279	E-4	0.143	E-3	0.182	E-3	0.554	E-4
29.7								
30.7								
25.8	0.149	E+6	0.141	E+6	0.133	E+6	0.126	E+6
26.6	-0.451	E+3	0.915	E+3	-0.126	E+4	-0.165	E+4
27.8	2803.		2883.		2913.		2963.	
28.8	0.279	E-4	0.143	E-3	0.182	E-3	0.554	E-4
29.8								
30.8								
25								
25.9	0.150	E+6	0.141	E+6	0.133	E+6	0.126	E+6
26.9	-0.497	E+3	-0.101	E+4	-0.138	E+4	-0.182	E+4
27.9	2803.		2883.		2913.		2963.	
28.9	0.279	E-4	0.143	E-3	0.182	E-3	0.554	E-4
29.9								
30.9								

FORTRAN Coding Form

FULLNOZ

11 14

CARD NO	FORTRAN STATEMENT							
25.10	0·150	E+6	0·142	E+6	0·134	E+6	0·126	E+6
26.10	-0·552	E+3	-0·112	E+4	-0·154	E+4	-0·202	E+4
27.10	2793·		2873·		2903·		2933·	
28.10	0·279	E-4	0·143	E-3	0·182	E-3	0·554	E-4
29.10								
30.10								
25.11	0·151	E+6	0·143	E+6	0·134	E+6	[illegible]	E+6
26.11	-0·621	E+3	0·126	E+4	-0·173	E+4	[illegible]	[illegible]
27.11	2793·		2873·		2903·		[illegible]	
28.11	0·279	E-4	0·143	E-3	0·182	[illegible]	[illegible]·554	E-4
29.11								
30.11								
25.12	0·152	E+6	0·143	E+6	0·135	E+6	0·127	E+6
26.12	-0·709	E+3	-0·144	E+4	-0·198	E+4	-0·260	E+4
27.12	2783·		2873·		2893·		2943·	
28.12	0·279	E-4	0·143	E-3	0·182	E-3	0·554	E-4
29.12								
30.12								
25.13	0·153	E+6	0·144	E+6	0·136	E+6	0·128	E+6
26.13	-0·828	E+3	-0·168	E+4	-0·231	E+4	-0·303	E+4
27.13	2783·		2873·		2893·		2943·	

FORTRAN Coding Form

FULLNOZ

12 14

CARD NO								
28.13	0·279	E-4	0·143	E-3	0·182	E-3	0·554	E-4
29.13								
30.13								
25.14	0·154	E+6	0·145	E+6	0·136	E+6	0·128	E+6
26.14	-0·993	E+3	-0·201	E+4	-0·277	E+4	-0·363	E+4
27.14	2763·		2853·		2883·		2933·	
28.14	0·279	E-4	0·143	E-3	0·182	E-3	0·554	E-4
29.14								
30.14								
25.15	0·155	E+6	0·146	E+6	0·137	E+6	0·129	E+6
26.15	-0·124	E+4	-0·252	E+4	-0·346	E+4	-0·454	E+4
27.15	2763·		2853·		2883·		2933·	
28.15	0·279	E-4	0·143	E-3	0·182	E-3	0·554	E-4
29.15								
30.15								
25.16	0·156	E+6	0·147	E+6	0·138	E+6	0·130	E+6
26.16	-0·166	E+4	-0·336	E+4	-0·461	E+4	-0·606	E+4
27.16	2743·		2823·		2873·		2923·	
28.16	0·279	E-4	0·143	E-3	0·182	E-3	0·554	E-4
29.16								
30.16								

FORTRAN Coding Form

FULLNOZ — 13 14

CARD NO								
25.17	0·158	E+6	0·149	E+6	0·139	E+6	0·131	E+6
26.17	-0·218	E+4	-0·504	E+4	-0·692	E+4	-0·909	E+4
27.17	2743·		2823·		2873·		2923·	
28.17	0·279	E-4	0·143	E-3	0·182	E-3	0·554	E-4
29.17								
30.17								
25.18	0·159	E+6	0·180	E+6	0·140	E+6	0·132	E+6
26.18	-0·497	E+4	-0·101	E+5	-0·138	E+5	-0·182	E+5
27.18	2713·		2793·		2853·		2903·	
28.18	0·279	E-4	0·143	E-3	0·182	E-3	0·554	E-4
29.18								
30.18								
31		10·7		10·7		10·7		10·7
32		0·0		0·0		0·0		0·0

FORTRAN Coding Form

FULLNOZ — 14 14

CARD NO										
33.1	O	+O	+M	=O2	+M	21	1	0E-29	·0	
.2	O	+H	+M	=OH	+M	22	1	0E-29	1·0	
.3	H	+H	+M	=H2	+M	22	5	0E-29	1·0	
.4	H	+OH	+M	=H2O	+M	22	2	0E-28	1·0	
.5	CO	+O	+M	=CO2	+M	26	1·0E-29		1·0	-2500
.6	OH	+OH		=OH2	+O	15	1	0E-11		-780·
.7	OH	+H2		=H2O	+H	15	3·6E-11			-5200·
.8	O	+H2		=OH	+H	15	2·9E-11			-9460·
.9	H	+O2		=OH	+O	15	3·7E-10			-16800·
.10	CO	+OH		=CO2	+H	15	9	0E-13		-1080

APPENDIX B

SAMPLE OUTPUT

FULLY COUPLED NOZZLE FLOW PROGRAM

AEROCHEM RESEARCH LABORATORIES, INC.
PRINCETON, NEW JERSEY 08540
*** FULLY COUPLED NOZZLE FLOW PROGRAM - FULLNOZ - SAMPLE TEST CASE 9/75 ***

NO. OF DATA SETS 1
NSECT= 7200 CALSS= 2.000E+02 ALPHAS= 1.524E+02 XLMUDB=0. IMUX =0 NNTB =0

NMAX	NN	NP	IP	ITYPE	IKIND	MMAX	NMAX	NUS	IVO	NITER	IDIFF	LPLANE
25	4	10	0	1	1	2	22	10	-0	50	0	900
IPTUL	IPCM	ISHOCK	IBUGSH	IIO	ICSH	ITAPES	IKINE	IPART	IKI	ITUMB	IPTO	
-0	-0	-0	0	-0	-0	-0	10	1	-0	0	-0	

NETAP	HO	NLIM
1.015UE+00	4.1020E+07	1.9671E+00

ALPHAN	EPSLON	TOL	DELTA	ATOL	FSTEP	GRAD	FRAC	FRACTN
.400	.010	.100E-03	1.0	.140	-0.00	-0.00	-0.00	-0.00

IDENT	WOD	TO	OMEGA	PH	SC	WA
CO	1.390E-04	3.000E+02	7.500E-01	1.400E+00	1.400E+00	2.800E+01
CO2	1.390E-04	3.000E+02	7.500E-01	1.400E+00	1.400E+00	4.400E+01
H	8.350E-05	3.000E+02	7.500E-01	1.400E+00	1.400E+00	1.000E+00
H2	8.350E-05	3.000E+02	7.500E-01	1.400E+00	1.400E+00	2.000E+00
OH	1.255E-04	3.000E+02	7.500E-01	1.400E+00	1.400E+00	1.700E+01
H2O	1.255E-04	3.000E+02	7.500E-01	1.400E+00	1.400E+00	1.800E+01
N2	1.600E-04	3.000E+02	7.500E-01	1.400E+00	1.400E+00	2.800E+01
O	1.660E-04	3.000E+02	7.500E-01	1.400E+00	1.400E+00	1.600E+01
O2	1.690E-04	3.000E+02	7.500E-01	1.400E+00	1.400E+00	3.200E+01
K	1.297E-04	3.000E+02	7.500E-01	1.400E+00	1.400E+00	4.000E+01

K	X	W	PHI	P	T	U
1	1.267E+01	0.	0.			
2	1.266E+01	6.053E-01	1.804E-02	8.500E+00	2.761E+03	1.534E+05
3	1.265E+01	1.211E+00	3.607E-02	8.473E+00	2.759E+03	1.534E+05
4	1.262E+01	1.816E+00	5.411E-02	8.443E+00	2.758E+03	1.535E+05
5	1.258E+01	2.420E+00	7.214E-02	8.400E+00	2.757E+03	1.537E+05
6	1.253E+01	3.024E+00	9.018E-02	8.345E+00	2.755E+03	1.539E+05
7	1.247E+01	3.626E+00	1.082E-01	8.273E+00	2.751E+03	1.541E+05
8	1.240E+01	4.227E+00	1.263E-01	8.193E+00	2.745E+03	1.546E+05
9	1.232E+01	4.828E+00	1.443E-01	8.103E+00	2.739E+03	1.551E+05
10	1.223E+01	5.426E+00	1.623E-01	8.003E+00	2.732E+03	1.556E+05
11	1.212E+01	6.023E+00	1.804E-01	7.895E+00	2.726E+03	1.563E+05
12	1.201E+01	6.618E+00	1.984E-01	7.775E+00	2.719E+03	1.571E+05
13	1.189E+01	7.210E+00	2.164E-01	7.645E+00	2.712E+03	1.579E+05
14	1.175E+01	7.800E+00	2.345E-01	7.498E+00	2.708E+03	1.588E+05
15	1.160E+01	8.388E+00	2.525E-01	7.328E+00	2.700E+03	1.600E+05
16	1.145E+01	8.973E+00	2.705E-01	7.138E+00	2.688E+03	1.614E+05
17	1.128E+01	9.555E+00	2.886E-01	6.935E+00	2.671E+03	1.630E+05
18	1.110E+01	1.013E+01	3.066E-01	6.715E+00	2.648E+03	1.648E+05
19	1.091E+01	1.071E+01	3.246E-01	6.480E+00	2.624E+03	1.671E+05
20	1.072E+01	1.128E+01	3.427E-01	6.225E+00	2.594E+03	1.676E+05
21	1.051E+01	1.185E+01	3.607E-01	5.950E+00	2.563E+03	1.720E+05
22	1.029E+01	1.242E+01	3.787E-01	5.680E+00	2.550E+03	1.762E+05
23	1.006E+01	1.298E+01	3.968E-01	5.390E+00	2.533E+03	1.798E+05
24	9.821E+00	1.353E+01	4.148E-01	5.065E+00	2.502E+03	1.847E+05
25	9.572E+00	1.408E+01	4.328E-01	4.802E+00	2.401E+03	1.908E+05

I	XA	WA	PHIA	PA	SA
1	1.267E+01	0.	0.	-0.	-0.
2	1.000E+10	-0.	-0.	-0.	-0.

N	XB	WB	PHIB	PB	SB
1	9.572E+00	1.408E+01	-0.	-0.	-0.
2	9.957E+00	1.428E+01	-0.	-0.	-0.
3	1.031E+01	1.450E+01	-0.	-0.	-0.
4	1.150E+01	1.522E+01	-0.	-0.	-0.
5	1.285E+01	1.585E+01	-0.	-0.	-0.
6	1.412E+01	1.643E+01	-0.	-0.	-0.
7	1.660E+01	1.773E+01	-0.	-0.	-0.
8	1.920E+01	1.900E+01	-0.	-0.	-0.
9	2.174E+01	2.022E+01	-0.	-0.	-0.
10	2.662E+01	2.201E+01	-0.	-0.	-0.
11	3.190E+01	2.494E+01	-0.	-0.	-0.
12	3.698E+01	2.731E+01	-0.	-0.	-0.
13	4.400E+01	3.068E+01	-0.	-0.	-0.
14	5.222E+01	3.390E+01	-0.	-0.	-0.
15	5.984E+01	3.708E+01	-0.	-0.	-0.
16	7.391E+01	4.098E+01	-0.	-0.	-0.
17	8.717E+01	4.684E+01	-0.	-0.	-0.
18	9.903E+01	5.075E+01	-0.	-0.	-0.
19	1.112E+02	5.451E+01	-0.	-0.	-0.
20	1.235E+02	5.804E+01	-0.	-0.	-0.
21	1.344E+02	6.091E+01	-0.	-0.	-0.
22	1.524E+02	6.563E+01	-0.	-0.	-0.

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-1      X= 0.            M= 0.            PHIM= 0.

 2      X= 1.2005E+01    M= 6.0530E-01    PHI= 1.0040E-02  T= 2.7610E+03    P= 8.5000E+00      U= 1.5300E+05
        MA=  .1277E+01   DELTX=  .6053E+00 H=  .1067E+03    HT=  .3880E+03   TAA= 0.            Q= 0.
        PT=  .1714E+02   RHO=  .7443E-03  SX= 0.            SUMDOT=  .1310E+03

        SPECIE  CO        C=  .3000E+00    X=  .2125E+00    ADOT= 0.
        SPECIE  CO2       C=  .6000E-01    X=  .2704E-01    ADOT= 0.
        SPECIE  H         C=  .6300E-03    X=  .1249E-01    ADOT= 0.
        SPECIE  H2        C=  .2400E-01    X=  .2380E+00    ADOT= 0.
        SPECIE  OH        C=  .2600E-02    X=  .3033E-02    ADOT= 0.
        SPECIE  H2O       C=  .1900E+00    X=  .2093E+00    ADOT= 0.
        SPECIE  N2        C=  .4200E+00    X=  .2975E+00    ADOT= 0.
        SPECIE  O         C=  .7800E-04    X=  .9668E-04    ADOT= 0.
        SPECIE  O2        C=  .5600E-04    X=  .3471E-04    ADOT= 0.
        SPECIE  N         C=  .1100E-05    X=  .5454E-06    ADOT= 0.

 3      X= 1.2040E+01    M= 1.2110E+00    PHI= 3.0070E-02  T= 2.7590E+03    P= 8.0750E+00      U= 1.5342E+05
        MA=  .1270E+01   DELTX=  .6050E+00 H=  .1057E+03    HT=  .3871E+03   TAA= 0.            Q= 0.
        PT=  .1710E+02   RHO=  .7424E-03  SX= 0.            SUMDOT=  .5253E+03

        SPECIE  CO        C=  .3000E+00    X=  .2125E+00    ADOT= 0.
        SPECIE  CO2       C=  .6000E-01    X=  .2704E-01    ADOT= 0.
        SPECIE  H         C=  .6300E-03    X=  .1249E-01    ADOT= 0.
        SPECIE  H2        C=  .2400E-01    X=  .2380E+00    ADOT= 0.
        SPECIE  OH        C=  .2600E-02    X=  .3033E-02    ADOT= 0.
        SPECIE  H2O       C=  .1900E+00    X=  .2093E+00    ADOT= 0.
        SPECIE  N2        C=  .4200E+00    X=  .2975E+00    ADOT= 0.
        SPECIE  O         C=  .7800E-04    X=  .9668E-04    ADOT= 0.
        SPECIE  O2        C=  .5600E-04    X=  .3471E-04    ADOT= 0.
        SPECIE  N         C=  .1100E-05    X=  .5454E-06    ADOT= 0.

 4      X= 1.2019E+01    M= 1.8150E+00    PHI= 5.0110E-02  T= 2.7580E+03    P= 8.0450E+00      U= 1.5508E+05
        MA=  .1279E+01   DELTX=  .6054E+00 H=  .1052E+03    HT=  .3806E+03   TAA= 0.            Q= 0.
        PT=  .1705E+02   RHO=  .7401E-03  SX= 0.            SUMDOT=  .1179E+00

        SPECIE  CO        C=  .3000E+00    X=  .2125E+00    ADOT= 0.
        SPECIE  CO2       C=  .6000E-01    X=  .2704E-01    ADOT= 0.
        SPECIE  H         C=  .6300E-03    X=  .1249E-01    ADOT= 0.
        SPECIE  H2        C=  .2400E-01    X=  .2380E+00    ADOT= 0.
        SPECIE  OH        C=  .2600E-02    X=  .3033E-02    ADOT= 0.
        SPECIE  H2O       C=  .1900E+00    X=  .2093E+00    ADOT= 0.
        SPECIE  N2        C=  .4200E+00    X=  .2975E+00    ADOT= 0.
        SPECIE  O         C=  .7800E-04    X=  .9668E-04    ADOT= 0.
        SPECIE  O2        C=  .5600E-04    X=  .3471E-04    ADOT= 0.
        SPECIE  N         C=  .1100E-05    X=  .5454E-06    ADOT= 0.

 5      X= 1.2581E+01    M= 2.4199E+00    PHI= 7.0140E-02  T= 2.7570E+03    P= 8.0000E+00      U= 1.5365E+05
        MA=  .1280E+01   DELTX=  .6053E+00 H=  .1047E+03    HT=  .3869E+03   TAA= 0.            Q= 0.
        PT=  .1698E+02   RHO=  .7388E-03  SX= 0.            SUMDOT=  .2091E+00

        SPECIE  CO        C=  .3000E+00    X=  .2125E+00    ADOT= 0.
        SPECIE  CO2       C=  .6000E-01    X=  .2704E-01    ADOT= 0.
        SPECIE  H         C=  .6300E-03    X=  .1249E-01    ADOT= 0.
        SPECIE  H2        C=  .2400E-01    X=  .2380E+00    ADOT= 0.
        SPECIE  OH        C=  .2600E-02    X=  .3033E-02    ADOT= 0.
        SPECIE  H2O       C=  .1900E+00    X=  .2093E+00    ADOT= 0.
        SPECIE  N2        C=  .4200E+00    X=  .2975E+00    ADOT= 0.
        SPECIE  O         C=  .7800E-04    X=  .9668E-04    ADOT= 0.
        SPECIE  O2        C=  .5600E-04    X=  .3471E-04    ADOT= 0.
        SPECIE  N         C=  .1100E-05    X=  .5454E-06    ADOT= 0.

 6      X= 1.2532E+01    M= 3.0238E+00    PHI= 9.0100E-02  T= 2.7550E+03    P= 8.3430E+00      U= 1.5387E+05
        MA=  .1285E+01   DELTX=  .6059E+00 H=  .1037E+03    HT=  .3867E+03   TAA= 0.            Q= 0.
        PT=  .1690E+02   RHO=  .7321E-03  SX= 0.            SUMDOT=  .3250E+00

        SPECIE  CO        C=  .3000E+00    X=  .2125E+00    ADOT= 0.
        SPECIE  CO2       C=  .6000E-01    X=  .2704E-01    ADOT= 0.
        SPECIE  H         C=  .6300E-03    X=  .1249E-01    ADOT= 0.
        SPECIE  H2        C=  .2400E-01    X=  .2380E+00    ADOT= 0.
        SPECIE  OH        C=  .2600E-02    X=  .3033E-02    ADOT= 0.
        SPECIE  H2O       C=  .1900E+00    X=  .2093E+00    ADOT= 0.
        SPECIE  N2        C=  .4200E+00    X=  .2975E+00    ADOT= 0.
        SPECIE  O         C=  .7800E-04    X=  .9668E-04    ADOT= 0.
        SPECIE  O2        C=  .5600E-04    X=  .3471E-04    ADOT= 0.
        SPECIE  N         C=  .1100E-05    X=  .5454E-06    ADOT= 0.

 7      X= 1.2472E+01    M= 3.6262E+00    PHI= 1.0021E-01  T= 2.7510E+03    P= 8.2730E+00      U= 1.5413E+05
        MA=  .1288E+01   DELTX=  .6054E+00 H=  .1018E+03    HT=  .3857E+03   TAA= 0.            Q= 0.
        PT=  .1680E+02   RHO=  .7270E-03  SX= 0.            SUMDOT=  .4675E+00

        SPECIE  CO        C=  .3000E+00    X=  .2125E+00    ADOT= 0.
        SPECIE  CO2       C=  .6000E-01    X=  .2704E-01    ADOT= 0.
        SPECIE  H         C=  .6300E-03    X=  .1249E-01    ADOT= 0.
        SPECIE  H2        C=  .2400E-01    X=  .2380E+00    ADOT= 0.
        SPECIE  OH        C=  .2600E-02    X=  .3033E-02    ADOT= 0.
        SPECIE  H2O       C=  .1900E+00    X=  .2093E+00    ADOT= 0.
        SPECIE  N2        C=  .4200E+00    X=  .2975E+00    ADOT= 0.
        SPECIE  O         C=  .7800E-04    X=  .9668E-04    ADOT= 0.
        SPECIE  O2        C=  .5600E-04    X=  .3471E-04    ADOT= 0.
        SPECIE  N         C=  .1100E-05    X=  .5454E-06    ADOT= 0.
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8    X= 1.2401E+01     M= 8.2270E+00     PHI= 1.2625E-01  T= 2.7450E+03    P= 8.1930E+00     U= 1.5456E+05
     MAS=  .1291E+01   DELTA=  .6050E+00 H=  .9060E+02    HT=  .3842E+03   TAM= 0.           Q= 0.
     PI=  .1670E+02    RHO=  .7210E-03   SX= 0.           SUMDOT=  .6341E+04

     SPECIE  CO          C=  .3000E+00    X=  .2125E+00    ADOT= 0.
     SPECIE  CO2         C=  .6000E-01    X=  .2704E-01    ADOT= 0.
     SPECIE  H           C=  .6300E-03    X=  .1249E-01    ADOT= 0.
     SPECIE  H2          C=  .2400E-01    X=  .2380E+00    ADOT= 0.
     SPECIE  OH          C=  .2600E-02    X=  .3033E-02    ADOT= 0.
     SPECIE  H2O         C=  .1900E+00    X=  .2093E+00    ADOT= 0.
     SPECIE  N2          C=  .4200E+00    X=  .2975E+00    ADOT= 0.
     SPECIE  O           C=  .7800E-04    X=  .9668E-04    ADOT= 0.
     SPECIE  O2          C=  .5600E-04    X=  .3471E-04    ADOT= 0.
     SPECIE  N           C=  .1100E-05    X=  .5454E-06    ADOT= 0.

9    X= 1.2319E+01     M= 8.8278E+00     PHI= 1.4420E-01  T= 2.7390E+03    P= 8.1030E+00     U= 1.5505E+05
     MAS=  .1290E+01   DELTA=  .6080E+00 H=  .9550E+02    HT=  .3830E+03   TAM= 0.           Q= 0.
     PI=  .1659E+02    RHO=  .7152E-03   SX= 0.           SUMDOT=  .8253E+04

     SPECIE  CO          C=  .3000E+00    X=  .2125E+00    ADOT= 0.
     SPECIE  CO2         C=  .6000E-01    X=  .2704E-01    ADOT= 0.
     SPECIE  H           C=  .6300E-03    X=  .1249E-01    ADOT= 0.
     SPECIE  H2          C=  .2400E-01    X=  .2380E+00    ADOT= 0.
     SPECIE  OH          C=  .2600E-02    X=  .3033E-02    ADOT= 0.
     SPECIE  H2O         C=  .1900E+00    X=  .2093E+00    ADOT= 0.
     SPECIE  N2          C=  .4200E+00    X=  .2975E+00    ADOT= 0.
     SPECIE  O           C=  .7800E-04    X=  .9668E-04    ADOT= 0.
     SPECIE  O2          C=  .5600E-04    X=  .3471E-04    ADOT= 0.
     SPECIE  N           C=  .1100E-05    X=  .5454E-06    ADOT= 0.

10   X= 1.2227E+01     M= 5.8280E+00     PHI= 1.6232E-01  T= 2.7320E+03    P= 8.0030E+00     U= 1.5561E+05
     MAS=  .1302E+01   DELTA=  .6052E+00 H=  .9202E+02    HT=  .3815E+03   TAM= 0.           Q= 0.
     PI=  .1647E+02    RHO=  .7062E-03   SX= 0.           SUMDOT=  .1040E+05

     SPECIE  CO          C=  .3000E+00    X=  .2125E+00    ADOT= 0.
     SPECIE  CO2         C=  .6000E-01    X=  .2704E-01    ADOT= 0.
     SPECIE  H           C=  .6300E-03    X=  .1249E-01    ADOT= 0.
     SPECIE  H2          C=  .2400E-01    X=  .2380E+00    ADOT= 0.
     SPECIE  OH          C=  .2600E-02    X=  .3033E-02    ADOT= 0.
     SPECIE  H2O         C=  .1900E+00    X=  .2093E+00    ADOT= 0.
     SPECIE  N2          C=  .4200E+00    X=  .2975E+00    ADOT= 0.
     SPECIE  O           C=  .7800E-04    X=  .9668E-04    ADOT= 0.
     SPECIE  O2          C=  .5600E-04    X=  .3471E-04    ADOT= 0.
     SPECIE  N           C=  .1100E-05    X=  .5454E-06    ADOT= 0.

11   X= 1.2123E+01     M= 6.0225E+00     PHI= 1.8035E-01  T= 2.7260E+03    P= 7.8950E+00     U= 1.5629E+05
     MAS=  .1509E+01   DELTA=  .6055E+00 H=  .8899E+02    HT=  .3810E+03   TAM= 0.           Q= 0.
     PI=  .1634E+02    RHO=  .7002E-03   SX= 0.           SUMDOT=  .1278E+05

     SPECIE  CO          C=  .3000E+00    X=  .2125E+00    ADOT= 0.
     SPECIE  CO2         C=  .6000E-01    X=  .2704E-01    ADOT= 0.
     SPECIE  H           C=  .6300E-03    X=  .1249E-01    ADOT= 0.
     SPECIE  H2          C=  .2400E-01    X=  .2380E+00    ADOT= 0.
     SPECIE  OH          C=  .2600E-02    X=  .3033E-02    ADOT= 0.
     SPECIE  H2O         C=  .1900E+00    X=  .2093E+00    ADOT= 0.
     SPECIE  N2          C=  .4200E+00    X=  .2975E+00    ADOT= 0.
     SPECIE  O           C=  .7800E-04    X=  .9668E-04    ADOT= 0.
     SPECIE  O2          C=  .5600E-04    X=  .3471E-04    ADOT= 0.
     SPECIE  N           C=  .1100E-05    X=  .5454E-06    ADOT= 0.

12   X= 1.2009E+01     M= 6.6176E+00     PHI= 1.9634E-01  T= 2.7190E+03    P= 7.7750E+00     U= 1.5707E+05
     MAS=  .1318E+01   DELTA=  .6059E+00 H=  .8545E+02    HT=  .3804E+03   TAM= 0.           Q= 0.
     PI=  .1619E+02    RHO=  .6913E-03   SX= 0.           SUMDOT=  .1540E+05

     SPECIE  CO          C=  .3000E+00    X=  .2125E+00    ADOT= 0.
     SPECIE  CO2         C=  .6000E-01    X=  .2704E-01    ADOT= 0.
     SPECIE  H           C=  .6300E-03    X=  .1249E-01    ADOT= 0.
     SPECIE  H2          C=  .2400E-01    X=  .2380E+00    ADOT= 0.
     SPECIE  OH          C=  .2600E-02    X=  .3033E-02    ADOT= 0.
     SPECIE  H2O         C=  .1900E+00    X=  .2093E+00    ADOT= 0.
     SPECIE  N2          C=  .4200E+00    X=  .2975E+00    ADOT= 0.
     SPECIE  O           C=  .7800E-04    X=  .9668E-04    ADOT= 0.
     SPECIE  O2          C=  .5600E-04    X=  .3471E-04    ADOT= 0.
     SPECIE  N           C=  .1100E-05    X=  .5454E-06    ADOT= 0.

13   X= 1.1885E+01     M= 7.2100E+00     PHI= 2.1042E-01  T= 2.7120E+03    P= 7.6650E+00     U= 1.5789E+05
     MAS=  .1326E+01   DELTA=  .6052E+00 H=  .8192E+02    HT=  .3800E+03   TAM= 0.           Q= 0.
     PI=  .1606E+02    RHO=  .6813E-03   SX= 0.           SUMDOT=  .1823E+05

     SPECIE  CO          C=  .3000E+00    X=  .2125E+00    ADOT= 0.
     SPECIE  CO2         C=  .6000E-01    X=  .2704E-01    ADOT= 0.
     SPECIE  H           C=  .6300E-03    X=  .1249E-01    ADOT= 0.
     SPECIE  H2          C=  .2400E-01    X=  .2380E+00    ADOT= 0.
     SPECIE  OH          C=  .2600E-02    X=  .3033E-02    ADOT= 0.
     SPECIE  H2O         C=  .1900E+00    X=  .2093E+00    ADOT= 0.
     SPECIE  N2          C=  .4200E+00    X=  .2975E+00    ADOT= 0.
     SPECIE  O           C=  .7800E-04    X=  .9668E-04    ADOT= 0.
     SPECIE  O2          C=  .5600E-04    X=  .3471E-04    ADOT= 0.
     SPECIE  N           C=  .1100E-05    X=  .5454E-06    ADOT= 0.
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14   X= 1.1749E+01    M= 7.0000E+00    PHI= 2.5000E-01  T= 2.7000E+03   P= 7.0900E+00    U= 1.5000E+05
     MA= .1335E+01    DELTA= .6059E+00 H= .7990E+02     HT= .3814E+03   TAU= 0.          W= 0.
     PT= .1503E+02    RHO= .6094E-03   S= 0.            SUMDOT= .2120E+05

     SPECIE  CO       C= .3000E+00   X= .2125E+00   NDOT= 0.
     SPECIE  CO2      C= .6000E-01   X= .2704E-01   NDOT= 0.
     SPECIE  H        C= .6300E-03   X= .1249E-01   NDOT= 0.
     SPECIE  H2       C= .2400E-01   X= .2300E+00   NDOT= 0.
     SPECIE  OH       C= .2600E-02   X= .3033E-02   NDOT= 0.
     SPECIE  H2O      C= .1900E+00   X= .2093E+00   NDOT= 0.
     SPECIE  N2       C= .4200E+00   X= .2975E+00   NDOT= 0.
     SPECIE  O        C= .7000E-04   X= .9668E-04   NDOT= 0.
     SPECIE  O2       C= .5600E-04   X= .3471E-04   NDOT= 0.
     SPECIE  N        C= .1100E-05   X= .5454E-06   NDOT= 0.
15   X= 1.1603E+01    M= 8.3000E+00    PHI= 2.5200E-01  T= 2.7000E+03   P= 7.1200E+00    U= 1.6001E+05
     MA= .1347E+01    DELTA= .6059E+00 H= .7580E+02     HT= .3820E+03   TAU= 0.          W= 0.
     PT= .1502E+02    RHO= .6501E-03   S= 0.            SUMDOT= .2050E+05

     SPECIE  CO       C= .3000E+00   X= .2125E+00   NDOT= 0.
     SPECIE  CO2      C= .6000E-01   X= .2704E-01   NDOT= 0.
     SPECIE  H        C= .6300E-03   X= .1249E-01   NDOT= 0.
     SPECIE  H2       C= .2400E-01   X= .2300E+00   NDOT= 0.
     SPECIE  OH       C= .2600E-02   X= .3033E-02   NDOT= 0.
     SPECIE  H2O      C= .1900E+00   X= .2093E+00   NDOT= 0.
     SPECIE  N2       C= .4200E+00   X= .2975E+00   NDOT= 0.
     SPECIE  O        C= .7000E-04   X= .9668E-04   NDOT= 0.
     SPECIE  O2       C= .5600E-04   X= .3471E-04   NDOT= 0.
     SPECIE  N        C= .1100E-05   X= .5454E-06   NDOT= 0.
16   X= 1.1447E+01    M= 8.9720E+00    PHI= 2.7053E-01  T= 2.6800E+03   P= 7.1300E+00    U= 1.6137E+05
     MA= .1361E+01    DELTA= .6053E+00 H= .6942E+02     HT= .3812E+03   TAU= 0.          W= 0.
     PT= .1539E+02    RHO= .6420E-03   S= 0.            SUMDOT= .2793E+05

     SPECIE  CO       C= .3000E+00   X= .2125E+00   NDOT= 0.
     SPECIE  CO2      C= .6000E-01   X= .2704E-01   NDOT= 0.
     SPECIE  H        C= .6300E-03   X= .1249E-01   NDOT= 0.
     SPECIE  H2       C= .2400E-01   X= .2300E+00   NDOT= 0.
     SPECIE  OH       C= .2600E-02   X= .3033E-02   NDOT= 0.
     SPECIE  H2O      C= .1900E+00   X= .2093E+00   NDOT= 0.
     SPECIE  N2       C= .4200E+00   X= .2975E+00   NDOT= 0.
     SPECIE  O        C= .7000E-04   X= .9668E-04   NDOT= 0.
     SPECIE  O2       C= .5600E-04   X= .3471E-04   NDOT= 0.
     SPECIE  N        C= .1100E-05   X= .5454E-06   NDOT= 0.
17   X= 1.1280E+01    M= 9.5540E+00    PHI= 2.8050E-01  T= 2.6710E+03   P= 6.9350E+00    U= 1.6290E+05
     MA= .1379E+01    DELTA= .6053E+00 H= .6124E+02     HT= .3780E+03   TAU= 0.          W= 0.
     PT= .1514E+02    RHO= .6277E-03   S= 0.            SUMDOT= .3152E+05

     SPECIE  CO       C= .3000E+00   X= .2125E+00   NDOT= 0.
     SPECIE  CO2      C= .6000E-01   X= .2704E-01   NDOT= 0.
     SPECIE  H        C= .6300E-03   X= .1249E-01   NDOT= 0.
     SPECIE  H2       C= .2400E-01   X= .2300E+00   NDOT= 0.
     SPECIE  OH       C= .2600E-02   X= .3033E-02   NDOT= 0.
     SPECIE  H2O      C= .1900E+00   X= .2093E+00   NDOT= 0.
     SPECIE  N2       C= .4200E+00   X= .2975E+00   NDOT= 0.
     SPECIE  O        C= .7000E-04   X= .9668E-04   NDOT= 0.
     SPECIE  O2       C= .5600E-04   X= .3471E-04   NDOT= 0.
     SPECIE  N        C= .1100E-05   X= .5454E-06   NDOT= 0.
18   X= 1.1102E+01    M= 1.0134E+01    PHI= 3.0000E-01  T= 2.6400E+03   P= 6.7150E+00    U= 1.6478E+05
     MA= .1400E+01    DELTA= .6061E+00 H= .4971E+02     HT= .3743E+03   TAU= 0.          W= 0.
     PT= .1493E+02    RHO= .6131E-03   S= 0.            SUMDOT= .3531E+05

     SPECIE  CO       C= .3000E+00   X= .2125E+00   NDOT= 0.
     SPECIE  CO2      C= .6000E-01   X= .2704E-01   NDOT= 0.
     SPECIE  H        C= .6300E-03   X= .1249E-01   NDOT= 0.
     SPECIE  H2       C= .2400E-01   X= .2300E+00   NDOT= 0.
     SPECIE  OH       C= .2600E-02   X= .3033E-02   NDOT= 0.
     SPECIE  H2O      C= .1900E+00   X= .2093E+00   NDOT= 0.
     SPECIE  N2       C= .4200E+00   X= .2975E+00   NDOT= 0.
     SPECIE  O        C= .7000E-04   X= .9668E-04   NDOT= 0.
     SPECIE  O2       C= .5600E-04   X= .3471E-04   NDOT= 0.
     SPECIE  N        C= .1100E-05   X= .5454E-06   NDOT= 0.
19   X= 1.0918E+01    M= 1.0704E+01    PHI= 3.2403E-01  T= 2.6240E+03   P= 6.6800E+00    U= 1.6705E+05
     MA= .1425E+01    DELTA= .6050E+00 H= .3767E+02     HT= .3713E+03   TAU= 0.          W= 0.
     PT= .1470E+02    RHO= .5970E-03   S= 0.            SUMDOT= .3020E+05

     SPECIE  CO       C= .3000E+00   X= .2125E+00   NDOT= 0.
     SPECIE  CO2      C= .6000E-01   X= .2704E-01   NDOT= 0.
     SPECIE  H        C= .6300E-03   X= .1249E-01   NDOT= 0.
     SPECIE  H2       C= .2400E-01   X= .2300E+00   NDOT= 0.
     SPECIE  OH       C= .2600E-02   X= .3033E-02   NDOT= 0.
     SPECIE  H2O      C= .1900E+00   X= .2093E+00   NDOT= 0.
     SPECIE  N2       C= .4200E+00   X= .2975E+00   NDOT= 0.
     SPECIE  O        C= .7000E-04   X= .9668E-04   NDOT= 0.
     SPECIE  O2       C= .5600E-04   X= .3471E-04   NDOT= 0.
     SPECIE  N        C= .1100E-05   X= .5454E-06   NDOT= 0.
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20   X= 1.0710E+01    M= 1.1201E+01    PHI= 3.6207E-01  T= 2.5900E+03   P= 6.2050E+00    U= 1.6763E+05
     MA=  .1038E+01   DELV=  .0053E+00 H=  .2267E+02    MT=  .3506E+03   TAM= 0.          G= 0.
     PT=  .1627E+02   RHO=  .5002E-03  SX= 0.           SUMDOT=  .0388E+05

     SPECIE  CO        C=  .3000E+00    X=  .2125E+00    ADOT= 0.
     SPECIE  CO2       C=  .6000E-01    X=  .2704E-01    ADOT= 0.
     SPECIE  H         C=  .6300E-03    X=  .1249E-01    ADOT= 0.
     SPECIE  H2        C=  .2400E-01    X=  .2380E+00    ADOT= 0.
     SPECIE  OH        C=  .2600E-02    X=  .3033E-02    ADOT= 0.
     SPECIE  H2O       C=  .1900E+00    X=  .2093E+00    ADOT= 0.
     SPECIE  N2        C=  .4200E+00    X=  .2975E+00    ADOT= 0.
     SPECIE  O         C=  .7800E-04    X=  .9668E-04    ADOT= 0.
     SPECIE  O2        C=  .5600E-04    X=  .3471E-04    ADOT= 0.
     SPECIE  A         C=  .1100E-05    X=  .5454E-06    ADOT= 0.

21   X= 1.0507E+01    M= 1.1050E+01    PHI= 3.0070E-01  T= 2.5650E+03   P= 5.9500E+00    U= 1.7256E+05
     MA=  .1488E+01   DELV=  .0062E+00 H=  .7201E+01    MT=  .3632E+03   TAM= 0.          G= 0.
     PT=  .1626E+02   RHO=  .5612E-03  SX= 0.           SUMDOT=  .4759E+05

     SPECIE  CO        C=  .3000E+00    X=  .2125E+00    ADOT= 0.
     SPECIE  CO2       C=  .6000E-01    X=  .2704E-01    ADOT= 0.
     SPECIE  H         C=  .6300E-03    X=  .1249E-01    ADOT= 0.
     SPECIE  H2        C=  .2400E-01    X=  .2380E+00    ADOT= 0.
     SPECIE  OH        C=  .2600E-02    X=  .3033E-02    ADOT= 0.
     SPECIE  H2O       C=  .1900E+00    X=  .2093E+00    ADOT= 0.
     SPECIE  N2        C=  .4200E+00    X=  .2975E+00    ADOT= 0.
     SPECIE  O         C=  .7800E-04    X=  .9668E-04    ADOT= 0.
     SPECIE  O2        C=  .5600E-04    X=  .3471E-04    ADOT= 0.
     SPECIE  A         C=  .1100E-05    X=  .5454E-06    ADOT= 0.

22   X= 1.0289E+01    M= 1.2815E+01    PHI= 3.7874E-01  T= 2.5500E+03   P= 5.6000E+00    U= 1.7616E+05
     MA=  .1527E+01   DELV=  .0056E+00 H=  .7283E+00    MT=  .3718E+03   TAM= 0.          G= 0.
     PT=  .1393E+02   RHO=  .5305E-03  SX= 0.           SUMDOT= .5197E+05

     SPECIE  CO        C=  .3000E+00    X=  .2125E+00    ADOT= 0.
     SPECIE  CO2       C=  .6000E-01    X=  .2704E-01    ADOT= 0.
     SPECIE  H         C=  .6300E-03    X=  .1249E-01    ADOT= 0.
     SPECIE  H2        C=  .2400E-01    X=  .2380E+00    ADOT= 0.
     SPECIE  OH        C=  .2600E-02    X=  .3033E-02    ADOT= 0.
     SPECIE  H2O       C=  .1900E+00    X=  .2093E+00    ADOT= 0.
     SPECIE  N2        C=  .4200E+00    X=  .2975E+00    ADOT= 0.
     SPECIE  O         C=  .7800E-04    X=  .9668E-04    ADOT= 0.
     SPECIE  O2        C=  .5600E-04    X=  .3471E-04    ADOT= 0.
     SPECIE  A         C=  .1100E-05    X=  .5454E-06    ADOT= 0.

23   X= 1.0000E+01    M= 1.2975E+01    PHI= 3.9677E-01  T= 2.5330E+03   P= 5.3000E+00    U= 1.7981E+05
     MA=  .1559E+01   DELV=  .0050E+00 H= -.7725E+01    MT=  .3788E+03   TAM= 0.          G= 0.
     PT=  .1360E+02   RHO=  .5148E-03  SX= 0.           SUMDOT=  .5683E+05

     SPECIE  CO        C=  .3000E+00    X=  .2125E+00    ADOT= 0.
     SPECIE  CO2       C=  .6000E-01    X=  .2704E-01    ADOT= 0.
     SPECIE  H         C=  .6300E-03    X=  .1249E-01    ADOT= 0.
     SPECIE  H2        C=  .2400E-01    X=  .2380E+00    ADOT= 0.
     SPECIE  OH        C=  .2600E-02    X=  .3033E-02    ADOT= 0.
     SPECIE  H2O       C=  .1900E+00    X=  .2093E+00    ADOT= 0.
     SPECIE  N2        C=  .4200E+00    X=  .2975E+00    ADOT= 0.
     SPECIE  O         C=  .7800E-04    X=  .9668E-04    ADOT= 0.
     SPECIE  O2        C=  .5600E-04    X=  .3471E-04    ADOT= 0.
     SPECIE  A         C=  .1100E-05    X=  .5454E-06    ADOT= 0.

24   X= 9.8205E+00    M= 1.3532E+01    PHI= 4.1481E-01  T= 2.5020E+03   P= 5.0050E+00    U= 1.8472E+05
     MA=  .1611E+01   DELV=  .0063E+00 H= -.2311E+02    MT=  .3849E+03   TAM= 0.          G= 0.
     PT=  .1331E+02   RHO=  .4894E-03  SX= 0.           SUMDOT=  .6100E+05

     SPECIE  CO        C=  .3000E+00    X=  .2125E+00    ADOT= 0.
     SPECIE  CO2       C=  .6000E-01    X=  .2704E-01    ADOT= 0.
     SPECIE  H         C=  .6300E-03    X=  .1249E-01    ADOT= 0.
     SPECIE  H2        C=  .2400E-01    X=  .2380E+00    ADOT= 0.
     SPECIE  OH        C=  .2600E-02    X=  .3033E-02    ADOT= 0.
     SPECIE  H2O       C=  .1900E+00    X=  .2093E+00    ADOT= 0.
     SPECIE  N2        C=  .4200E+00    X=  .2975E+00    ADOT= 0.
     SPECIE  O         C=  .7800E-04    X=  .9668E-04    ADOT= 0.
     SPECIE  O2        C=  .5600E-04    X=  .3471E-04    ADOT= 0.
     SPECIE  A         C=  .1100E-05    X=  .5454E-06    ADOT= 0.

25   X= 9.5715E+00    M= 1.4184E+01    PHI= 4.3284E-01  T= 2.4610E+03   P= 4.6020E+00    U= 1.9043E+05
     MA=  .1694E+01   DELV=  .0058E+00 H= -.7243E+02    MT=  .3908E+03   TAM= 0.          G= 0.
     PT=  .1290E+02   RHO=  .4634E-03  SX= 0.           SUMDOT=  .6563E+05

     SPECIE  CO        C=  .3000E+00    X=  .2125E+00    ADOT= 0.
     SPECIE  CO2       C=  .6000E-01    X=  .2704E-01    ADOT= 0.
     SPECIE  H         C=  .6300E-03    X=  .1249E-01    ADOT= 0.
     SPECIE  H2        C=  .2400E-01    X=  .2380E+00    ADOT= 0.
     SPECIE  OH        C=  .2600E-02    X=  .3033E-02    ADOT= 0.
     SPECIE  H2O       C=  .1900E+00    X=  .2093E+00    ADOT= 0.
     SPECIE  N2        C=  .4200E+00    X=  .2975E+00    ADOT= 0.
     SPECIE  O         C=  .7800E-04    X=  .9668E-04    ADOT= 0.
     SPECIE  O2        C=  .5600E-04    X=  .3471E-04    ADOT= 0.
     SPECIE  A         C=  .1100E-05    X=  .5454E-06    ADOT= 0.
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$NAM1
FFF     = .1E+01,
FFG     = .1E+01,
UME     = -0.0,
TL      = .330E+00,
CS      = .123E+00,
TPG     = .250E+04,
RHOS    = .4E+01,
RT      = .100E+05,
HTRAN   = .295E+05,
SIG     = -0.0,
EP      = -0.0,
NPG     = 4,
NC      = 1,
NMX     = 10,
RP      = .1E-03, .2E-03, .3E-03, .4E-03, 0.0, 0.0, 0.0, 0.0,
RI      = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
VI      = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
TPI     = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
RHPI    = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
$END
STREAMLINE NO.      1
DOWNSTREAM VELOCITY      1.470E+05   1.390E+05   1.310E+05   1.240E+05
CROSS-STREAM VELOCITY   -2.760E+02  -5.590E+02  -7.680E+02  -1.010E+03
PARTICLE TEMPERATURE     2.813E+03   2.893E+03   2.913E+03   2.973E+03
PARTICLE DENSITY         2.790E-05   1.430E-04   1.020E-04   5.540E-05
STREAMLINE NO.      2
DOWNSTREAM VELOCITY      1.470E+05   1.390E+05   1.320E+05   1.250E+05
CROSS-STREAM VELOCITY   -2.920E+02  -5.920E+02  -8.140E+02  -1.070E+03
PARTICLE TEMPERATURE     2.813E+03   2.893E+03   2.913E+03   2.973E+03
PARTICLE DENSITY         2.790E-05   1.430E-04   1.020E-04   5.540E-05
STREAMLINE NO.      3
DOWNSTREAM VELOCITY      1.480E+05   1.390E+05   1.320E+05   1.250E+05
CROSS-STREAM VELOCITY   -3.100E+02  -6.290E+02  -8.640E+02  -1.100E+03
PARTICLE TEMPERATURE     2.813E+03   2.893E+03   2.913E+03   2.973E+03
PARTICLE DENSITY         2.790E-05   1.430E-04   1.020E-04   5.540E-05
STREAMLINE NO.      4
DOWNSTREAM VELOCITY      1.480E+05   1.390E+05   1.320E+05   1.250E+05
CROSS-STREAM VELOCITY   -3.310E+02  -6.710E+02  -9.220E+02  -1.210E+03
PARTICLE TEMPERATURE     2.813E+03   2.893E+03   2.913E+03   2.973E+03
PARTICLE DENSITY         2.790E-05   1.430E-04   1.020E-04   5.540E-05
STREAMLINE NO.      5
DOWNSTREAM VELOCITY      1.480E+05   1.400E+05   1.320E+05   1.250E+05
CROSS-STREAM VELOCITY   -3.550E+02  -7.190E+02  -9.880E+02  -1.300E+03
PARTICLE TEMPERATURE     2.813E+03   2.893E+03   2.913E+03   2.973E+03
PARTICLE DENSITY         2.790E-05   1.430E-04   1.020E-04   5.540E-05
STREAMLINE NO.      6
DOWNSTREAM VELOCITY      1.480E+05   1.400E+05   1.320E+05   1.250E+05
CROSS-STREAM VELOCITY   -3.820E+02  -7.750E+02  -1.060E+03  -1.400E+03
PARTICLE TEMPERATURE     2.813E+03   2.893E+03   2.913E+03   2.973E+03
PARTICLE DENSITY         2.790E-05   1.430E-04   1.020E-04   5.540E-05
STREAMLINE NO.      7
DOWNSTREAM VELOCITY      1.490E+05   1.400E+05   1.320E+05   1.250E+05
CROSS-STREAM VELOCITY   -4.140E+02  -8.390E+02  -1.150E+03  -1.510E+03
PARTICLE TEMPERATURE     2.803E+03   2.883E+03   2.913E+03   2.963E+03
PARTICLE DENSITY         2.790E-05   1.430E-04   1.020E-04   5.540E-05
STREAMLINE NO.      8
DOWNSTREAM VELOCITY      1.490E+05   1.410E+05   1.330E+05   1.260E+05
CROSS-STREAM VELOCITY   -4.510E+02  -9.150E+02  -1.260E+03  -1.650E+03
PARTICLE TEMPERATURE     2.803E+03   2.883E+03   2.913E+03   2.963E+03
PARTICLE DENSITY         2.790E-05   1.430E-04   1.020E-04   5.540E-05
STREAMLINE NO.      9
DOWNSTREAM VELOCITY      1.500E+05   1.410E+05   1.330E+05   1.260E+05
CROSS-STREAM VELOCITY   -4.970E+02  -1.010E+03  -1.380E+03  -1.820E+03
PARTICLE TEMPERATURE     2.803E+03   2.883E+03   2.913E+03   2.963E+03
PARTICLE DENSITY         2.790E-05   1.430E-04   1.020E-04   5.540E-05
STREAMLINE NO.     10
DOWNSTREAM VELOCITY      1.500E+05   1.420E+05   1.340E+05   1.260E+05
CROSS-STREAM VELOCITY   -5.520E+02  -1.120E+03  -1.540E+03  -2.020E+03
PARTICLE TEMPERATURE     2.793E+03   2.873E+03   2.903E+03   2.953E+03
PARTICLE DENSITY         2.790E-05   1.430E-04   1.020E-04   5.540E-05
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STREAMLINE NO. 11				
DOWNSTREAM VELOCITY	1.510E+05	1.430E+05	1.340E+05	1.270E+05
CROSS-STREAM VELOCITY	-6.210E+02	-1.200E+03	-1.730E+03	-2.270E+03
PARTICLE TEMPERATURE	2.703E+03	2.873E+03	2.903E+03	2.933E+03
PARTICLE DENSITY	2.790E-05	1.430E-04	1.020E-04	5.540E-05
STREAMLINE NO. 12				
DOWNSTREAM VELOCITY	1.520E+05	1.430E+05	1.350E+05	1.270E+05
CROSS-STREAM VELOCITY	-7.090E+02	-1.440E+03	-1.960E+03	-2.600E+03
PARTICLE TEMPERATURE	2.703E+03	2.873E+03	2.893E+03	2.943E+03
PARTICLE DENSITY	2.790E-05	1.430E-04	1.020E-04	5.540E-05
STREAMLINE NO. 13				
DOWNSTREAM VELOCITY	1.530E+05	1.440E+05	1.360E+05	1.280E+05
CROSS-STREAM VELOCITY	-8.200E+02	-1.680E+03	-2.310E+03	-3.030E+03
PARTICLE TEMPERATURE	2.703E+03	2.873E+03	2.893E+03	2.943E+03
PARTICLE DENSITY	2.790E-05	1.430E-04	1.020E-04	5.540E-05
STREAMLINE NO. 14				
DOWNSTREAM VELOCITY	1.540E+05	1.450E+05	1.360E+05	1.280E+05
CROSS-STREAM VELOCITY	-9.930E+02	-2.010E+03	-2.770E+03	-3.630E+03
PARTICLE TEMPERATURE	2.703E+03	2.853E+03	2.883E+03	2.933E+03
PARTICLE DENSITY	2.790E-05	1.430E-04	1.020E-04	5.540E-05
STREAMLINE NO. 15				
DOWNSTREAM VELOCITY	1.550E+05	1.460E+05	1.370E+05	1.290E+05
CROSS-STREAM VELOCITY	-1.290E+03	-2.520E+03	-3.460E+03	-4.540E+03
PARTICLE TEMPERATURE	2.703E+03	2.853E+03	2.883E+03	2.953E+03
PARTICLE DENSITY	2.790E-05	1.430E-04	1.020E-04	5.540E-05
STREAMLINE NO. 16				
DOWNSTREAM VELOCITY	1.560E+05	1.470E+05	1.380E+05	1.300E+05
CROSS-STREAM VELOCITY	-1.640E+03	-3.360E+03	-4.610E+03	-6.090E+03
PARTICLE TEMPERATURE	2.743E+03	2.823E+03	2.873E+03	2.923E+03
PARTICLE DENSITY	2.790E-05	1.430E-04	1.020E-04	5.540E-05
STREAMLINE NO. 17				
DOWNSTREAM VELOCITY	1.580E+05	1.490E+05	1.390E+05	1.310E+05
CROSS-STREAM VELOCITY	-2.400E+03	-5.040E+03	-6.920E+03	-9.090E+03
PARTICLE TEMPERATURE	2.743E+03	2.823E+03	2.873E+03	2.923E+03
PARTICLE DENSITY	2.790E-05	1.430E-04	1.020E-04	5.540E-05
STREAMLINE NO. 18				
DOWNSTREAM VELOCITY	1.590E+05	1.500E+05	1.400E+05	1.320E+05
CROSS-STREAM VELOCITY	-4.970E+03	-1.010E+04	-1.380E+04	-1.820E+04
PARTICLE TEMPERATURE	2.713E+03	2.793E+03	2.853E+03	2.903E+03
PARTICLE DENSITY	2.790E-05	1.430E-04	1.020E-04	5.540E-05
STREAMLINE NO. 19				
DOWNSTREAM VELOCITY	0.	0.	0.	0.
CROSS-STREAM VELOCITY	0.	0.	0.	0.
PARTICLE TEMPERATURE	0.	0.	0.	0.
PARTICLE DENSITY	0.	0.	0.	0.
STREAMLINE NO. 20				
DOWNSTREAM VELOCITY	0.	0.	0.	0.
CROSS-STREAM VELOCITY	0.	0.	0.	0.
PARTICLE TEMPERATURE	0.	0.	0.	0.
PARTICLE DENSITY	0.	0.	0.	0.
STREAMLINE NO. 21				
DOWNSTREAM VELOCITY	0.	0.	0.	0.
CROSS-STREAM VELOCITY	0.	0.	0.	0.
PARTICLE TEMPERATURE	0.	0.	0.	0.
PARTICLE DENSITY	0.	0.	0.	0.
STREAMLINE NO. 22				
DOWNSTREAM VELOCITY	0.	0.	0.	0.
CROSS-STREAM VELOCITY	0.	0.	0.	0.
PARTICLE TEMPERATURE	0.	0.	0.	0.
PARTICLE DENSITY	0.	0.	0.	0.
STREAMLINE NO. 23				
DOWNSTREAM VELOCITY	0.	0.	0.	0.
CROSS-STREAM VELOCITY	0.	0.	0.	0.
PARTICLE TEMPERATURE	0.	0.	0.	0.
PARTICLE DENSITY	0.	0.	0.	0.
STREAMLINE NO. 24				
DOWNSTREAM VELOCITY	0.	0.	0.	0.
CROSS-STREAM VELOCITY	0.	0.	0.	0.
PARTICLE TEMPERATURE	0.	0.	0.	0.
PARTICLE DENSITY	0.	0.	0.	0.
STREAMLINE NO. 25				
DOWNSTREAM VELOCITY	0.	0.	0.	0.
CROSS-STREAM VELOCITY	0.	0.	0.	0.
PARTICLE TEMPERATURE	0.	0.	0.	0.
PARTICLE DENSITY	0.	0.	0.	0.

1	O	O	O2	M	22	.10E-28 1.0	-0.0
2	O	H	OH	M	22	.10E-28 1.0	-0.0
3	H	H	H2	M	22	.20E-29 1.0	-0.0
4	H	OH	H2O	M	22	.20E-27 1.0	-0.0
5	CO	O	CO2	M	26	.10E-28 1.0	-2500.0
6	OH	OH	H2O	O	15	.10E-10-0.0	-1000.0
7	OH	H2	H2O	H	15	.50E-10-0.0	-5200.0
8	O	H2	OH	H	15	.50E-10-0.0	-8400.0
9	H	O2	OH	O	15	.30E-09-0.0	-16500.0
10	CO	OH	CO2	H	15	.50E-12-0.0	-600.0

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 1  70        XN=  .2200E+02   HN= 0.            PHIN= 0.

     2   X= 2.2000E+01     R= 0.2200E-01     PHI= 2.2441E-02  T= 2.0505E+03    P= 3.1135E+00     U= 2.0096E+05
         MA=  .1775E+01    DELY=  .8225E+00 H= -.7110E+02     HT=  .4117E+03   TANG 0.           Q= 0.
         PI=  .9247E+01    RHO=  .3077E-03  SX=  .1021E+02    SUMDOT=  .1310E+03

         SPECIE  CO         C=  .2961E+00    X=  .2106E+00    WDOT= -.8819E-04
         SPECIE  CO2        C=  .6017E-01    X=  .2995E-01    WDOT=  .8819E-04
         SPECIE  H          C=  .3123E-03    X=  .6221E-02    WDOT=  .1055E-02
         SPECIE  H2         C=  .2440E-01    X=  .2450E+00    WDOT= -.1008E-02
         SPECIE  OH         C=  .8500E-03    X=  .9965E-03    WDOT= -.1430E-02
         SPECIE  H2O        C=  .1895E+00    X=  .2096E+00    WDOT=  .1390E-02
         SPECIE  N2         C=  .4200E+00    X=  .2988E+00    WDOT= 0.
         SPECIE  O          C=  .1277E-04    X=  .1590E-04    WDOT= -.1495E-04
         SPECIE  O2         C=  .1144E-04    X=  .7123E-05    WDOT=  .4630E-06
         SPECIE  N          C=  .1100E-05    X=  .5477E-06    WDOT= 0.

     3   X= 2.2000E+01     R= 1.6419E+00     PHI= 4.4616E-02  T= 2.0520E+03    P= 3.1105E+00     U= 2.0121E+05
         MA=  .1777E+01    DELY=  .8204E+00 H= -.7332E+02     HT=  .4107E+03   TANG 0.           Q= 0.
         PI=  .9276E+01    RHO=  .3083E-03  SX=  .1020E+02    SUMDOT=  .5253E+03

         SPECIE  CO         C=  .2963E+00    X=  .2108E+00    WDOT= -.3996E-04
         SPECIE  CO2        C=  .6579E-01    X=  .2970E-01    WDOT=  .3996E-04
         SPECIE  H          C=  .3095E-03    X=  .6085E-02    WDOT=  .1237E-02
         SPECIE  H2         C=  .2447E-01    X=  .2437E+00    WDOT= -.1190E-02
         SPECIE  OH         C=  .8809E-03    X=  .9053E-03    WDOT= -.1210E-02
         SPECIE  H2O        C=  .1890E+00    X=  .2090E+00    WDOT=  .1180E-02
         SPECIE  N2         C=  .4200E+00    X=  .2980E+00    WDOT= 0.
         SPECIE  O          C=  .1259E-04    X=  .1567E-04    WDOT= -.1223E-04
         SPECIE  O2         C=  .1098E-04    X=  .6819E-05    WDOT=  .3642E-06
         SPECIE  N          C=  .1100E-05    X=  .5478E-06    WDOT= 0.

     4   X= 2.2745E+01     R= 2.4595E+00     PHI= 6.7190E-02  T= 2.0530E+03    P= 3.1140E+00     U= 2.0109E+05
         MA=  .1775E+01    DELY=  .8188E+00 H= -.7272E+02     HT=  .4107E+03   TANG 0.           Q= 0.
         PI=  .9260E+01    RHO=  .3082E-03  SX=  .1020E+02    SUMDOT=  .1179E+04

         SPECIE  CO         C=  .2967E+00    X=  .2110E+00    WDOT= -.3044E-04
         SPECIE  CO2        C=  .6524E-01    X=  .2953E-01    WDOT=  .3044E-04
         SPECIE  H          C=  .3055E-03    X=  .6086E-02    WDOT=  .9002E-03
         SPECIE  H2         C=  .2445E-01    X=  .2435E+00    WDOT= -.9512E-03
         SPECIE  OH         C=  .8562E-03    X=  .1003E-02    WDOT= -.9654E-03
         SPECIE  H2O        C=  .1898E+00    X=  .2101E+00    WDOT=  .9430E-03
         SPECIE  N2         C=  .4200E+00    X=  .2988E+00    WDOT= 0.
         SPECIE  O          C=  .1308E-04    X=  .1628E-04    WDOT= -.9337E-05
         SPECIE  O2         C=  .1092E-04    X=  .6794E-05    WDOT=  .2669E-06
         SPECIE  N          C=  .1100E-05    X=  .5478E-06    WDOT= 0.

     5   X= 2.2750E+01     R= 3.2754E+00     PHI= 9.0314E-02  T= 2.0542E+03    P= 3.1082E+00     U= 2.0105E+05
         MA=  .1775E+01    DELY=  .8184E+00 H= -.7242E+02     HT=  .4108E+03   TANG 0.           Q= 0.
         PI=  .9243E+01    RHO=  .3075E-03  SX=  .1019E+02    SUMDOT=  .2091E+04

         SPECIE  CO         C=  .2967E+00    X=  .2111E+00    WDOT= -.2898E-04
         SPECIE  CO2        C=  .6517E-01    X=  .2950E-01    WDOT=  .2898E-04
         SPECIE  H          C=  .3088E-03    X=  .6106E-02    WDOT=  .9517E-03
         SPECIE  H2         C=  .2444E-01    X=  .2434E+00    WDOT= -.9242E-03
         SPECIE  OH         C=  .8625E-03    X=  .1011E-02    WDOT= -.9577E-03
         SPECIE  H2O        C=  .1898E+00    X=  .2101E+00    WDOT=  .9172E-03
         SPECIE  N2         C=  .4200E+00    X=  .2988E+00    WDOT= 0.
         SPECIE  O          C=  .1328E-04    X=  .1651E-04    WDOT= -.8985E-05
         SPECIE  O2         C=  .1102E-04    X=  .6859E-05    WDOT=  .2510E-06
         SPECIE  N          C=  .1100E-05    X=  .5478E-06    WDOT= 0.

     6   X= 2.2647E+01     R= 4.0897E+00     PHI= 1.1276E-01  T= 2.0536E+03    P= 3.0975E+00     U= 2.0106E+05
         MA=  .1775E+01    DELY=  .8185E+00 H= -.7240E+02     HT=  .4105E+03   TANG 0.           Q= 0.
         PI=  .9214E+01    RHO=  .3065E-03  SX=  .1017E+02    SUMDOT=  .3258E+04

         SPECIE  CO         C=  .2972E+00    X=  .2114E+00    WDOT= -.1450E-04
         SPECIE  CO2        C=  .6446E-01    X=  .2918E-01    WDOT=  .1450E-04
         SPECIE  H          C=  .3037E-03    X=  .6050E-02    WDOT=  .5838E-03
         SPECIE  H2         C=  .2441E-01    X=  .2431E+00    WDOT= -.5769E-03
         SPECIE  OH         C=  .8733E-03    X=  .1023E-02    WDOT= -.5778E-03
         SPECIE  H2O        C=  .1901E+00    X=  .2104E+00    WDOT=  .5679E-03
         SPECIE  N2         C=  .4200E+00    X=  .2988E+00    WDOT= 0.
         SPECIE  O          C=  .1367E-04    X=  .1702E-04    WDOT= -.4785E-05
         SPECIE  O2         C=  .1074E-04    X=  .6686E-05    WDOT=  .10[illegible]
         SPECIE  N          C=  .1100E-05    X=  .5478E-06    WDOT= 0.

     7   X= 2.2540E+01     R= 4.9004E+00     PHI= 1.3520E-01  T= 2.0527E+03    P= 3.0801E+00     U= 2.0091E+05
         MA=  .1774E+01    DELY=  .8170E+00 H= -.7332E+02     HT=  .4093E+03   TANG 0.           Q= 0.
         PI=  .9179E+01    RHO=  .3057E-03  SX=  .1015E+02    SUMDOT=  .4675E+04

         SPECIE  CO         C=  .2974E+00    X=  .2116E+00    WDOT= -.8347E-05
         SPECIE  CO2        C=  .6409E-01    X=  .2901E-01    WDOT=  .8347E-05
         SPECIE  H          C=  .3018E-03    X=  .6012E-02    WDOT=  .3991E-03
         SPECIE  H2         C=  .2440E-01    X=  .2430E+00    WDOT= -.3923E-03
         SPECIE  OH         C=  .8755E-03    X=  .1026E-02    WDOT= -.3969E-03
         SPECIE  H2O        C=  .1903E+00    X=  .2106E+00    WDOT=  .3912E-03
         SPECIE  N2         C=  .4200E+00    X=  .2988E+00    WDOT= 0.
         SPECIE  O          C=  .1378E-04    X=  .1716E-04    WDOT= -.2755E-05
         SPECIE  O2         C=  .1053E-04    X=  .6555E-05    WDOT=  .8603E-07
         SPECIE  N          C=  .1100E-05    X=  .5478E-06    WDOT= 0.
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8    X= 2.2027E+01    M= 5.7091E+00    PHI= 1.5023E-01   T= 2.4517E+03   P= 3.0722E+00    U= 2.0092E+05
     MA=  .1779E+01   DELTA=  .0175E+00 H= -.7303E+02   HT=  .4000E+03   TAU= 0.           Q= 0.
     PI=  .9135E+01   RHO=  .3003E-03  SX=  .1013E+02   SUMDOT=  .6341E+04

     SPECIE  CO        C=  .2976E+00    X=  .2117E+00    WDOT= -.1299E-05
     SPECIE  CO2       C=  .6373E-01    X=  .2089E-01    WDOT=  .1299E-05
     SPECIE  H         C=  .3005E-03    X=  .5905E-02    WDOT=  .2159E-03
     SPECIE  H2        C=  .2030E-01    X=  .2429E+00    WDOT= -.2162E-03
     SPECIE  OH        C=  .8009E-03    X=  .1032E-02    WDOT= -.2177E-03
     SPECIE  H2O       C=  .1900E+00    X=  .2107E+00    WDOT=  .2171E-03
     SPECIE  N2        C=  .4200E+00    X=  .2900E+00    WDOT= 0.
     SPECIE  O         C=  .1399E-04    X=  .1742E-04    WDOT= -.6430E-06
     SPECIE  O2        C=  .1039E-04    X=  .6405E-05    WDOT= -.2197E-07
     SPECIE  A         C=  .1100E-05    X=  .5470E-06    WDOT= 0.
9    X= 2.2200E+01    M= 6.5153E+00    PHI= 1.8167E-01   T= 2.4400E+03   P= 3.0500E+00    U= 2.0111E+05
     MA=  .1777E+01   DELTA=  .0181E+00 H= -.7557E+02   HT=  .4080E+03   TAU= 0.           Q= 0.
     PI=  .9091E+01   RHO=  .3025E-03  SX=  .1011E+02   SUMDOT=  .8253E+04

     SPECIE  CO        C=  .2976E+00    X=  .2117E+00    WDOT= -.1516E-05
     SPECIE  CO2       C=  .6378E-01    X=  .2087E-01    WDOT=  .1516E-05
     SPECIE  H         C=  .2976E-03    X=  .5920E-02    WDOT=  .2109E-03
     SPECIE  H2        C=  .2439E-01    X=  .2429E+00    WDOT= -.2109E-03
     SPECIE  OH        C=  .8600E-03    X=  .1010E-02    WDOT= -.2205E-03
     SPECIE  H2O       C=  .1900E+00    X=  .2107E+00    WDOT=  .2197E-03
     SPECIE  N2        C=  .4200E+00    X=  .2900E+00    WDOT= 0.
     SPECIE  O         C=  .1367E-04    X=  .1702E-04    WDOT= -.6977E-06
     SPECIE  O2        C=  .1016E-04    X=  .6323E-05    WDOT= -.1917E-07
     SPECIE  A         C=  .1100E-05    X=  .5470E-06    WDOT= 0.
10   X= 2.2139E+01    M= 7.3192E+00    PHI= 2.0620E-01   T= 2.4444E+03   P= 3.0177E+00    U= 2.0127E+05
     MA=  .1780E+01   DELTA=  .0193E+00 H= -.7790E+02   HT=  .4065E+03   TAU= 0.           Q= 0.
     PI=  .9012E+01   RHO=  .2990E-03  SX=  .1008E+02   SUMDOT=  .1040E+05

     SPECIE  CO        C=  .2975E+00    X=  .2117E+00    WDOT= -.2208E-05
     SPECIE  CO2       C=  .6389E-01    X=  .2093E-01    WDOT=  .2208E-05
     SPECIE  H         C=  .2943E-03    X=  .5862E-02    WDOT=  .2434E-03
     SPECIE  H2        C=  .2440E-01    X=  .2430E+00    WDOT= -.2427E-03
     SPECIE  OH        C=  .8548E-03    X=  .1002E-02    WDOT= -.2446E-03
     SPECIE  H2O       C=  .1904E+00    X=  .2107E+00    WDOT=  .2434E-03
     SPECIE  N2        C=  .4200E+00    X=  .2908E+00    WDOT= 0.
     SPECIE  O         C=  .1330E-04    X=  .1657E-04    WDOT= -.9036E-06
     SPECIE  O2        C=  .9932E-05    X=  .6103E-05    WDOT= -.1390E-07
     SPECIE  A         C=  .1100E-05    X=  .5478E-06    WDOT= 0.
11   X= 2.1952E+01    M= 8.1207E+00    PHI= 2.3153E-01   T= 2.4393E+03   P= 2.9801E+00    U= 2.0167E+05
     MA=  .1786E+01   DELTA=  .0211E+00 H= -.8071E+02   HT=  .4058E+03   TAU= 0.           Q= 0.
     PI=  .8936E+01   RHO=  .2967E-03  SX=  .1005E+02   SUMDOT=  .1270E+05

     SPECIE  CO        C=  .2975E+00    X=  .2117E+00    WDOT= -.2430E-05
     SPECIE  CO2       C=  .6396E-01    X=  .2096E-01    WDOT=  .2430E-05
     SPECIE  H         C=  .2900E-03    X=  .5776E-02    WDOT=  .2467E-03
     SPECIE  H2        C=  .2440E-01    X=  .2431E+00    WDOT= -.2457E-03
     SPECIE  OH        C=  .8370E-03    X=  .9809E-03    WDOT= -.2477E-03
     SPECIE  H2O       C=  .1904E+00    X=  .2107E+00    WDOT=  .2463E-03
     SPECIE  N2        C=  .4200E+00    X=  .2908E+00    WDOT= 0.
     SPECIE  O         C=  .1284E-04    X=  .1599E-04    WDOT= -.9468E-06
     SPECIE  O2        C=  .9608E-05    X=  .5981E-05    WDOT= -.1129E-07
     SPECIE  A         C=  .1100E-05    X=  .5479E-06    WDOT= 0.
12   X= 2.1753E+01    M= 8.9213E+00    PHI= 2.5695E-01   T= 2.4363E+03   P= 2.9360E+00    U= 2.0207E+05
     MA=  .1790E+01   DELTA=  .0250E+00 H= -.8237E+02   HT=  .4058E+03   TAU= 0.           Q= 0.
     PI=  .8830E+01   RHO=  .2927E-03  SX=  .1001E+02   SUMDOT=  .1540E+05

     SPECIE  CO        C=  .2975E+00    X=  .2117E+00    WDOT= -.2401E-05
     SPECIE  CO2       C=  .6398E-01    X=  .2097E-01    WDOT=  .2401E-05
     SPECIE  H         C=  .2880E-03    X=  .5738E-02    WDOT=  .2362E-03
     SPECIE  H2        C=  .2440E-01    X=  .2431E+00    WDOT= -.2353E-03
     SPECIE  OH        C=  .8274E-03    X=  .9697E-03    WDOT= -.2372E-03
     SPECIE  H2O       C=  .1904E+00    X=  .2107E+00    WDOT=  .2350E-03
     SPECIE  N2        C=  .4200E+00    X=  .2908E+00    WDOT= 0.
     SPECIE  O         C=  .1261E-04    X=  .1570E-04    WDOT= -.9171E-06
     SPECIE  O2        C=  .9429E-05    X=  .5870E-05    WDOT= -.9623E-08
     SPECIE  A         C=  .1100E-05    X=  .5479E-06    WDOT= 0.
13   X= 2.1532E+01    M= 9.7190E+00    PHI= 2.8287E-01   T= 2.4316E+03   P= 2.8849E+00    U= 2.0250E+05
     MA=  .1796E+01   DELTA=  .0277E+00 H= -.8442E+02   HT=  .4054E+03   TAU= 0.           Q= 0.
     PI=  .8717E+01   RHO=  .2881E-03  SX=  .9969E+01   SUMDOT=  .1823E+05

     SPECIE  CO        C=  .2974E+00    X=  .2116E+00    WDOT= -.2292E-05
     SPECIE  CO2       C=  .6402E-01    X=  .2099E-01    WDOT=  .2292E-05
     SPECIE  H         C=  .2844E-03    X=  .5671E-02    WDOT=  .2241E-03
     SPECIE  H2        C=  .2441E-01    X=  .2432E+00    WDOT= -.2232E-03
     SPECIE  OH        C=  .8125E-03    X=  .9522E-03    WDOT= -.2251E-03
     SPECIE  H2O       C=  .1904E+00    X=  .2107E+00    WDOT=  .2237E-03
     SPECIE  N2        C=  .4206E+00    X=  .2909E+00    WDOT= 0.
     SPECIE  O         C=  .1224E-04    X=  .1524E-04    WDOT= -.8520E-06
     SPECIE  O2        C=  .9151E-05    X=  .5697E-05    WDOT= -.8023E-08
     SPECIE  A         C=  .1100E-05    X=  .5479E-06    WDOT= 0.
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14   X= 2.1209E+01    M= 1.1515E+01    PHI= 3.1042E-01  T= 2.4209E+03   P= 2.8230E+00    U= 2.0319E+05
     MAS= .1004E+01   DELTA= .8363E+00 H= -.8610E+02    HI= .0070E+03   TAMB 0.          UB 0.
     RIS= .8577E+01   RHOS= .2023E-03  SX= .9920E+01    SUMDOTS= .2120E+05

     SPECIE  CO        C= .2974E+00    X= .2110E+00     ADOTS= -.2350E-05
     SPECIE  CO2       C= .6405E-01    X= .2960E-01     ADOTS=  .2350E-05
     SPECIE  H         C= .2851E-03    X= .5670E-02     ADOTS=  .2205E-03
     SPECIE  H2        C= .2441E-01    X= .2432E+00     ADOTS= -.2195E-03
     SPECIE  OH        C= .8112E-03    X= .9500E-03     ADOTS= -.2215E-03
     SPECIE  H2O       C= .1904E+00    X= .2107E+00     ADOTS=  .2200E-03
     SPECIE  N2        C= .4200E+00    X= .2498E+00     ADOTS= 0.
     SPECIE  O         C= .1224E-04    X= .1524E-04     ADOTS= -.8827E-06
     SPECIE  O2        C= .9154E-05    X= .5049E-05     ADOTS= -.7695E-08
     SPECIE  N         C= .1100E-05    X= .5479E-06     ADOTS= 0.

15   X= 2.1020E+01    M= 1.1311E+01    PHI= 3.4117E-01  T= 2.4228E+03   P= 2.7404E+00    U= 2.0398E+0
     MAS= .1012E+01   DELTA= .8607E+00 H= -.8949E+02    HI= .4080E+03   TAMB 0.          UB 0.
     RIS= .8598E+01   RHOS= .2751E-03  SX= .9985E+01    SUMDOTS= .2450E+05

     SPECIE  CO        C= .2474E+00    X= .2110E+00     ADOTS= -.2503E-05
     SPECIE  CO2       C= .6415E-01    X= .2905E-01     ADOTS=  .2503E-05
     SPECIE  H         C= .2821E-03    X= .5621E-02     ADOTS=  .2245E-03
     SPECIE  H2        C= .2442E-01    X= .2432E+00     ADOTS= -.2233E-03
     SPECIE  OH        C= .7475E-03    X= .9500E-03     ADOTS= -.2250E-03
     SPECIE  H2O       C= .1913E+00    X= .2107E+00     ADOTS=  .2237E-03
     SPECIE  N2        C= .4200E+00    X= .2499E+00     ADOTS= 0.
     SPECIE  O         C= .1193E-04    X= .1485E-04     ADOTS= -.8597E-06
     SPECIE  O2        C= .8944E-05    X= .5589E-05     ADOTS= -.6670E-08
     SPECIE  N         C= .1100E-05    X= .5479E-06     ADOTS= 0.

16   X= 2.0721E+01    M= 1.2194E+01    PHI= 3.7606E-01  T= 2.4112E+03   P= 2.6600E+00    U= 2.0522E+05
     MAS= .1027E+01   DELTA= .8518E+00 H= -.9570E+02    HI= .6070E+03   TAMB 0.          UB 0.
     RIS= .8108E+01   RHOS= .2660E-03  SX= .9793E+01    SUMDOTS= .2792E+05

     SPECIE  CO        C= .2972E+00    X= .2115E+00     ADOTS= -.2544E-05
     SPECIE  CO2       C= .6432E-01    X= .2913E-01     ADOTS=  .2544E-05
     SPECIE  H         C= .2745E-03    X= .5409E-02     ADOTS=  .2235E-03
     SPECIE  H2        C= .2445E-01    X= .2430E+00     ADOTS= -.2222E-03
     SPECIE  OH        C= .7657E-03    X= .8974E-03     ADOTS= -.2243E-03
     SPECIE  H2O       C= .1905E+00    X= .2107E+00     ADOTS=  .2220E-03
     SPECIE  N2        C= .4200E+00    X= .2498E+00     ADOTS= 0.
     SPECIE  O         C= .1117E-04    X= .1392E-04     ADOTS= -.8500E-06
     SPECIE  O2        C= .8440E-05    X= .5233E-05     ADOTS= -.6039E-08
     SPECIE  N         C= .1100E-05    X= .5480E-06     ADOTS= 0.

17   X= 2.0585E+01    M= 1.2912E+01    PHI= 4.1494E-01  T= 2.3958E+03   P= 2.5110E+00    U= 2.0887E+05
     MAS= .1067E+01   DELTA= .8718E+00 H= -.1035E+03    HI= .4054E+03   TAMB 0.          UB 0.
     RIS= .7889E+01   RHOS= .2548E-03  SX= .9710E+01    SUMDOTS= .3152E+05

     SPECIE  CO        C= .2971E+00    X= .2115E+00     ADOTS= -.2514E-05
     SPECIE  CO2       C= .6450E-01    X= .2925E-01     ADOTS=  .2514E-05
     SPECIE  H         C= .2612E-03    X= .5200E-02     ADOTS=  .2047E-03
     SPECIE  H2        C= .2445E-01    X= .2430E+00     ADOTS= -.2035E-03
     SPECIE  OH        C= .7123E-03    X= .8350E-03     ADOTS= -.2055E-03
     SPECIE  H2O       C= .1905E+00    X= .2107E+00     ADOTS=  .2039E-03
     SPECIE  N2        C= .4260E+00    X= .2498E+00     ADOTS= 0.
     SPECIE  O         C= .9914E-05    X= .1235E-04     ADOTS= -.7250E-06
     SPECIE  O2        C= .7417E-05    X= .4050E-05     ADOTS= -.5367E-08
     SPECIE  N         C= .1100E-05    X= .5481E-06     ADOTS= 0.

18   X= 2.0098E+01    M= 1.3724E+01    PHI= 4.5799E-01  T= 2.3823E+03   P= 2.3675E+00    U= 2.0708E+05
     MAS= .1082E+01   DELTA= .9118E+00 H= -.1115E+03    HI= .4052E+03   TAMB 0.          UB 0.
     RIS= .7517E+01   RHOS= .2410E-03  SX= .9609E+01    SUMDOTS= .3531E+05

     SPECIE  CO        C= .2971E+00    X= .2115E+00     ADOTS= -.1570E-05
     SPECIE  CO2       C= .6455E-01    X= .2924E-01     ADOTS=  .1570E-05
     SPECIE  H         C= .2520E-03    X= .5030E-02     ADOTS=  .1479E-03
     SPECIE  H2        C= .2446E-01    X= .2437E+00     ADOTS= -.1472E-03
     SPECIE  OH        C= .6740E-03    X= .7904E-03     ADOTS= -.1488E-03
     SPECIE  H2O       C= .1904E+00    X= .2107E+00     ADOTS=  .1470E-03
     SPECIE  N2        C= .4200E+00    X= .2490E+00     ADOTS= 0.
     SPECIE  O         C= .9071E-05    X= .1130E-04     ADOTS= -.4900E-06
     SPECIE  O2        C= .6790E-05    X= .4224E-05     ADOTS= -.4171E-08
     SPECIE  N         C= .1100E-05    X= .5481E-06     ADOTS= 0.

19   X= 1.9599E+01    M= 1.4531E+01    PHI= 4.7055E-01  T= 2.3115E+03   P= 2.2072E+00    U= 2.1336E+05
     MAS= .1959E+01   DELTA= .8968E+00 H= -.1092E+03    HI= .3969E+03   TAMB 0.          UB 0.
     RIS= .7422E+01   RHOS= .2321E-03  SX= .9500E+01    SUMDOTS= .3926E+05

     SPECIE  CO        C= .2962E+00    X= .2109E+00     ADOTS= -.3329E-05
     SPECIE  CO2       C= .6599E-01    X= .2991E-01     ADOTS=  .3329E-05
     SPECIE  H         C= .2101E-03    X= .4191E-02     ADOTS=  .2208E-03
     SPECIE  H2        C= .2455E-01    X= .2440E+00     ADOTS= -.2259E-03
     SPECIE  OH        C= .5219E-03    X= .6122E-03     ADOTS= -.2241E-03
     SPECIE  H2O       C= .1899E+00    X= .2104E+00     ADOTS=  .2269E-03
     SPECIE  N2        C= .4200E+00    X= .2491E+00     ADOTS= 0.
     SPECIE  O         C= .5999E-05    X= .7472E-05     ADOTS= -.8088E-06
     SPECIE  O2        C= .4674E-05    X= .2913E-05     ADOTS= -.1051E-08
     SPECIE  N         C= .1100E-05    X= .5484E-06     ADOTS= 0.
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20   X= 1.9200E+01     M= 1.5217E+01     PHI= 4.2313E-01  T= 2.1991E+03     P= 2.3500E+00     U= 2.1805E+05
     MA=  .2030E+01    DELTA=  .7621E+00 H= -.2104E+03    HT=  .3500E+03    TAW= 0.           Q= 0.
     PT=  .9511E+01    RHO=  .2010E-03   S=  .9420E+01    SUMDOT=  .6332E+05

     SPECIE  CO         C=  .2950E+00     X=  .2103E+00     ADOT= -.2163E-06
     SPECIE  CO2        C=  .6789E-01     X=  .3080E-01     ADOT=  .2163E-06
     SPECIE  H          C=  .1125E-03     X=  .2240E-02     ADOT=  .5448E-04
     SPECIE  H2         C=  .2472E-01     X=  .2460E+00     ADOT= -.5409E-04
     SPECIE  OH         C=  .2260E-03     X=  .2004E-03     ADOT= -.5499E-04
     SPECIE  H2O        C=  .1090E+00     X=  .2101E+00     ADOT=  .5495E-04
     SPECIE  N2         C=  .4200E+00     X=  .2995E+00     ADOT= 0.
     SPECIE  O          C=  .1415E-05     X=  .1760E-05     ADOT= -.1085E-06
     SPECIE  O2         C=  .1088E-05     X=  .6780E-06     ADOT= -.8084E-09
     SPECIE  N          C=  .1100E-05     X=  .5490E-06     ADOT= 0.

21   X= 1.9003E+01     M= 1.5829E+01     PHI= 3.9354E-01  T= 2.2906E+03     P= 2.9415E+00     U= 2.1006E+05
     MA=  .1916E+01    DELTA=  .6663E+00 H= -.1855E+03    HT=  .3625E+03    TAW= 0.           Q= 0.
     PT=  .9747E+01    RHO=  .3125E-03   S=  .9391E+01    SUMDOT=  .4759E+05

     SPECIE  CO         C=  .2968E+00     X=  .2110E+00     ADOT=  .2753E-05
     SPECIE  CO2        C=  .6507E-01     X=  .2952E-01     ADOT= -.2754E-05
     SPECIE  H          C=  .1207E-03     X=  .2410E-02     ADOT= -.8812E-04
     SPECIE  H2         C=  .2459E-01     X=  .2454E+00     ADOT=  .8566E-04
     SPECIE  OH         C=  .2650E-03     X=  .3111E-03     ADOT= [illegible]E-04
     SPECIE  H2O        C=  .1905E+00     X=  .2113E+00     ADOT= -.8595E-04
     SPECIE  N2         C=  .4200E+00     X=  .2994E+00     ADOT= 0.
     SPECIE  O          C=  .1655E-05     X=  .2066E-05     ADOT=  .1799E-07
     SPECIE  O2         C=  .1153E-05     X=  .7195E-06     ADOT= -.7006E-09
     SPECIE  N          C=  .1100E-05     X=  .5490E-06     ADOT= 0.

22   X= 1.8718E+01     M= 1.6458E+01     PHI= 4.5705E-01  T= 2.2551E+03     P= 2.7600E+00     U= 2.1459E+05
     MA=  .1974E+01    DELTA=  .6908E+00 H= -.1006E+03    HT=  .3700E+03    TAW= 0.           Q= 0.
     PT=  .9320E+01    RHO=  .2913E-03   S=  .9356E+01    SUMDOT=  .5197E+05

     SPECIE  CO         C=  .2963E+00     X=  .2112E+00     ADOT= -.6408E-05
     SPECIE  CO2        C=  .6578E-01     X=  .2903E-01     ADOT=  .6408E-05
     SPECIE  H          C=  .1503E-03     X=  .2999E-02     ADOT=  .2003E-03
     SPECIE  H2         C=  .2459E-01     X=  .2454E+00     ADOT= -.1948E-03
     SPECIE  OH         C=  .3554E-03     X=  .4171E-03     ADOT= -.2020E-03
     SPECIE  H2O        C=  .1902E+00     X=  .2108E+00     ADOT=  .1956E-03
     SPECIE  N2         C=  .4201E+00     X=  .2993E+00     ADOT= 0.
     SPECIE  O          C=  .2954E-05     X=  .3684E-05     ADOT= -.5532E-07
     SPECIE  O2         C=  .2282E-05     X=  .1423E-05     ADOT=  .5499E-08
     SPECIE  N          C=  .1100E-05     X=  .5488E-06     ADOT= 0.

23   X= 1.8404E+01     M= 1.7094E+01     PHI= 4.5824E-01  T= 2.2512E+03     P= 2.5088E+00     U= 2.1826E+05
     MA=  .2018E+01    DELTA=  .7093E+00 H= -.1929E+03    HT=  .3706E+03    TAW= 0.           Q= 0.
     PT=  .8941E+01    RHO=  .2736E-03   S=  .9312E+01    SUMDOT=  .5643E+05

     SPECIE  CO         C=  .2950E+00     X=  .2102E+00     ADOT= -.2301E-05
     SPECIE  CO2        C=  .6742E-01     X=  .3081E-01     ADOT=  .2301E-05
     SPECIE  H          C=  .1422E-03     X=  .2837E-02     ADOT=  .2066E-03
     SPECIE  H2         C=  .2470E-01     X=  .2465E+00     ADOT= -.2053E-03
     SPECIE  OH         C=  .3143E-03     X=  .3690E-03     ADOT= -.2876E-03
     SPECIE  H2O        C=  .1893E+00     X=  .2099E+00     ADOT=  .2058E-03
     SPECIE  N2         C=  .4200E+00     X=  .2994E+00     ADOT= 0.
     SPECIE  O          C=  .2494E-05     X=  .3117E-05     ADOT= -.4811E-06
     SPECIE  O2         C=  .2018E-05     X=  .1259E-05     ADOT= -.3108E-08
     SPECIE  N          C=  .1101E-05     X=  .5488E-06     ADOT= 0.

24   X= 1.8094E+01     M= 1.7707E+01     PHI= 4.6525E-01  T= 2.2481E+03     P= 2.5833E+00     U= 2.1810E+05
     MA=  .2109E+01    DELTA=  .6847E+00 H= -.1849E+03    HT=  .3838E+03    TAW= 0.           Q= 0.
     PT=  .9147E+01    RHO=  .2796E-03   S=  .9277E+01    SUMDOT=  .6100E+05

     SPECIE  CO         C=  .2956E+00     X=  .2107E+00     ADOT= -.1199E-05
     SPECIE  CO2        C=  .6686E-01     X=  .3033E-01     ADOT=  .1199E-05
     SPECIE  H          C=  .1375E-03     X=  .2744E-02     ADOT=  .1205E-03
     SPECIE  H2         C=  .2485E-01     X=  .2480E+00     ADOT= -.1194E-03
     SPECIE  OH         C=  .3074E-03     X=  .3610E-03     ADOT= -.1212E-03
     SPECIE  H2O        C=  .1898E+00     X=  .2104E+00     ADOT=  .1203E-03
     SPECIE  N2         C=  .4200E+00     X=  .2994E+00     ADOT= 0.
     SPECIE  O          C=  .2321E-05     X=  .2896E-05     ADOT= -.2717E-06
     SPECIE  O2         C=  .1794E-05     X=  .1119E-05     ADOT= -.1007E-08
     SPECIE  N          C=  .1101E-05     X=  .5489E-06     ADOT= 0.

25   X= 1.7801E+01     M= 1.8303E+01     PHI= 4.6426E-01  T= 2.1585E+03     P= 2.6014E+00     U= 2.0957E+05
     MA=  .1989E+01    DELTA=  .6865E+00 H= -.2313E+03    HT=  .2938E+03    TAW= -.2977E+05   Q= -.1610E+03
     PT=  .8961E+01    RHO=  .2934E-03   S=  .9252E+01    SUMDOT=  .6563E+05

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                                   WALL TEMPERATURE= 1000. KELVIN

                                   BOUNDARY LAYER PARAMETERS

RETS=  [illegible]   DELTAI=  .2188E+00   THETAI=  .2123E-01   CFI=  .3703E-02   UFI=  .6138E+04
CISP=  [illegible]   DELTAC=  [illegible] THETAC=  .2438E-01   CFC=  .4626E-02   CFC/CFI=  .1248E+01
HI2=   [illegible]   ALCA= [illegible]    TAUWALL= -.2977E+05
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BOUNDARY LAYER PROFILES

U/UE	T/TE	U/UF INC	Y/DEL
.1000E-01	.4694E+00	.3045E+00	.2100E-03
.2000E-01	.4771E+00	.6067E+00	.4197E-03
.3000E-01	.4855E+00	.9064E+00	.6270E-03
.4000E-01	.4943E+00	.1203E+01	.8320E-03
.5000E-01	.5034E+00	.1498E+01	.1036E-02
.6000E-01	.5127E+00	.1789E+01	.1238E-02
.7000E-01	.5221E+00	.2078E+01	.1438E-02
.8000E-01	.5317E+00	.2365E+01	.1636E-02
.9000E-01	.5413E+00	.2649E+01	.1832E-02
.1000E+00	.5510E+00	.2930E+01	.2027E-02
.1500E+00	.5996E+00	.4296E+01	.2972E-02
.2000E+00	.6474E+00	.5609E+01	.3888E-02
.2500E+00	.6936E+00	.6875E+01	.5035E-02
.3000E+00	.7375E+00	.8101E+01	.6434E-02
.3500E+00	.7788E+00	.9292E+01	.8165E-02
.4000E+00	.8172E+00	.1045E+02	.1030E-01
.4500E+00	.8525E+00	.1159E+02	.1295E-01
.5000E+00	.8845E+00	.1270E+02	.1615E-01
.5500E+00	.9130E+00	.1380E+02	.2011E-01
.6000E+00	.9380E+00	.1488E+02	.3527E-01
.6500E+00	.9594E+00	.1595E+02	.5405E-01
.7000E+00	.9769E+00	.1700E+02	.8248E-01
.7500E+00	.9907E+00	.1805E+02	.1254E+00
.8000E+00	.1001E+01	.1909E+02	.1902E+00
.8500E+00	.1006E+01	.2013E+02	.2891E+00
.9000E+00	.1008E+01	.2117E+02	.4360E+00
.9500E+00	.1006E+01	.2220E+02	.6600E+00
.1000E+01	.1000E+01	.2324E+02	.1000E+01

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SPECIE  CO     C=  .2988E+00   X=  .2101E+00   ADOT= -.1007E-05
SPECIE  CO2    C=  .6844E-01   X=  .3106E-01   ADOT=  .1007E-05
SPECIE  H      C=  .9236E-04   X=  .1844E-02   ADOT=  .7067E-08
SPECIE  H2     C=  .2476E-01   X=  .2472E+00   ADOT= -.7867E-08
SPECIE  OH     C=  .1791E-03   X=  .2104E-03   ADOT= -.7925E-08
SPECIE  H2O    C=  .1893E+00   X=  .2100E+00   ADOT=  .7836E-08
SPECIE  N2     C=  .4200E+00   X=  .2995E+00   ADOT= 0.
SPECIE  O      C=  .9244E-06   X=  .1154E-05   ADOT= -.1173E-06
SPECIE  O2     C=  .7236E-06   X=  .4512E-06   ADOT= -.4391E-09
SPECIE  A      C=  .1110E-05   X=  .5492E-06   ADOT= 0.
---STREAMLINE=    1  S=    10.20905
 -- LOCAL GAS PROPERTIES
 U= 2.010E+05  T= 2.458E+03  DENSITY= 3.077E-04  REYNOLDS NO.= 6.911E+21  Y2= 6.225E-01  R2= 6.220E-01
----- PARTICLE PHASE PROPERTIES -----
PARTICLE GROUP              1            2            3            4
DOWNSTREAM VELOCITY      1.890E+05    1.681E+05    1.530E+05    1.421E+05
CROSS-STREAM VELOCITY   -3.756E+01   -2.959E+02   -5.585E+02   -8.415E+02
PARTICLE REYNOLDS NO.    1.228E+00    6.675E+00    1.453E+01    2.373E+01
PARTICLE TEMPERATURE     2.527E+03    2.634E+03    2.715E+03    2.792E+03
PARTICLE DENSITY         1.208E-05    7.015E-05    9.811E-05    3.204E-05
 PARTICLE MOMENTUM FLUX        2.650E+00
---STREAMLINE=    2  S=    10.20905
 -- LOCAL GAS PROPERTIES
 U= 2.012E+05  T= 2.455E+03  DENSITY= 3.083E-04  REYNOLDS NO.= 6.902E+21  Y2= 1.642E+00  R2= 1.642E+00
----- PARTICLE PHASE PROPERTIES -----
PARTICLE GROUP              1            2            3            4
DOWNSTREAM VELOCITY      1.892E+05    1.681E+05    1.535E+05    1.427E+05
CROSS-STREAM VELOCITY   -1.103E+02   -5.546E+02   -8.611E+02   -1.096E+03
PARTICLE REYNOLDS NO.    1.244E+00    6.740E+00    1.449E+01    2.366E+01
PARTICLE TEMPERATURE     2.523E+03    2.628E+03    2.710E+03    2.788E+03
PARTICLE DENSITY         1.207E-05    6.794E-05    9.200E-05    2.912E-05
 PARTICLE MOMENTUM FLUX        2.524E+00
---STREAMLINE=    3  S=    10.20905
 -- LOCAL GAS PROPERTIES
 U= 2.011E+05  T= 2.454E+03  DENSITY= 3.082E-04  REYNOLDS NO.= 6.877E+21  Y2= 2.461E+00  R2= 2.458E+00
----- PARTICLE PHASE PROPERTIES -----
PARTICLE GROUP              1            2            3            4
DOWNSTREAM VELOCITY      1.891E+05    1.681E+05    1.534E+05    1.426E+05
CROSS-STREAM VELOCITY   -2.399E+02   -8.670E+02   -1.252E+03   -1.525E+03
PARTICLE REYNOLDS NO.    1.233E+00    6.718E+00    1.447E+01    2.364E+01
PARTICLE TEMPERATURE     2.523E+03    2.628E+03    2.710E+03    2.788E+03
PARTICLE DENSITY         1.222E-05    6.815E-05    9.195E-05    2.902E-05
 PARTICLE MOMENTUM FLUX        2.524E+00
---STREAMLINE=    4  S=    10.20905
 -- LOCAL GAS PROPERTIES
 U= 2.010E+05  T= 2.454E+03  DENSITY= 3.075E-04  REYNOLDS NO.= 6.851E+21  Y2= 3.280E+00  R2= 3.275E+00
----- PARTICLE PHASE PROPERTIES -----
PARTICLE GROUP              1            2            3            4
DOWNSTREAM VELOCITY      1.891E+05    1.681E+05    1.534E+05    1.426E+05
CROSS-STREAM VELOCITY   -3.602E+02   -1.206E+03   -1.720E+03   -2.014E+03
PARTICLE REYNOLDS NO.    1.230E+00    6.694E+00    1.443E+01    2.358E+01
PARTICLE TEMPERATURE     2.523E+03    2.629E+03    2.711E+03    2.788E+03
PARTICLE DENSITY         1.224E-05    6.820E-05    9.188E-05    2.888E-05
 PARTICLE MOMENTUM FLUX        2.524E+00
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***STREAMLINE     5  S=    10.20905
 ** LOCAL GAS PROPERTIES
 U= 2.011E+05  T= 2.456E+03  DENSITY= 3.005E-04  REYNOLDS NO.= 6.825E+21  Y2= 6.000E+00  R2= 6.000E+00
***** PARTICLE PHASE PROPERTIES *****
PARTICLE GROUP              1           2           3           4
DOWNSTREAM VELOCITY     1.891E+05   1.688E+05   1.534E+05   1.426E+05
CROSS-STREAM VELOCITY  -6.755E+02  -1.071E+03  -2.145E+03  -2.511E+03
PARTICLE REYNOLDS NO.   1.232E+00   6.624E+00   1.441E+01   2.354E+01
PARTICLE TEMPERATURE    2.523E+03   2.620E+03   2.710E+03   2.780E+03
PARTICLE DENSITY        1.227E-05   6.873E-05   9.108E-05   2.889E-05
 PARTICLE MOMENTUM FLUX       2.535E+00
***STREAMLINE     6  S=    10.20905
 ** LOCAL GAS PROPERTIES
 U= 2.009E+05  T= 2.451E+03  DENSITY= 3.157E-04  REYNOLDS NO.= 6.768E+21  Y2= 6.915E+00  R2= 6.900E+00
***** PARTICLE PHASE PROPERTIES *****
PARTICLE GROUP              1                       3           4
DOWNSTREAM VELOCITY     1.890E+05   1.682E+05   1.533E+05   1.425E+05
CROSS-STREAM VELOCITY  -8.215E+02  -2.014E+03  -2.605E+03  -2.967E+03
PARTICLE REYNOLDS NO.   1.224E+00   6.608E+00   1.436E+01   2.346E+01
PARTICLE TEMPERATURE    2.521E+03   2.620E+03   2.708E+03   2.787E+03
PARTICLE DENSITY        1.231E-05   6.888E-05   9.201E-05   2.892E-05
 PARTICLE MOMENTUM FLUX       2.536E+00
***STREAMLINE     7  S=    10.20905
 ** LOCAL GAS PROPERTIES
 U= 2.009E+05  T= 2.452E+03  DENSITY= 3.063E-04  REYNOLDS NO.= 6.752E+21  Y2= 5.733E+00  R2= 5.704E+00
***** PARTICLE PHASE PROPERTIES *****
PARTICLE GROUP              1           2           3           4
DOWNSTREAM VELOCITY     1.890E+05   1.682E+05   1.533E+05   1.425E+05
CROSS-STREAM VELOCITY  -1.021E+03  -2.404E+03  -3.078E+03  -3.469E+03
PARTICLE REYNOLDS NO.   1.215E+00   6.565E+00   1.431E+01   2.337E+01
PARTICLE TEMPERATURE    2.519E+03   2.622E+03   2.707E+03   2.774E+03
PARTICLE DENSITY        1.241E-05   6.945E-05   9.218E-05   2.945E-05
 PARTICLE MOMENTUM FLUX       2.541E+00
***STREAMLINE     8  S=    10.20905
 ** LOCAL GAS PROPERTIES
 U= 2.011E+05  T= 2.449E+03  DENSITY= 3.125E-04  REYNOLDS NO.= 6.720E+21  Y2= 6.551E+00  R2= 6.515E+00
***** PARTICLE PHASE PROPERTIES *****
PARTICLE GROUP              1           2           3           4
DOWNSTREAM VELOCITY     1.891E+05   1.687E+05   1.546E+05   1.433E+05
CROSS-STREAM VELOCITY  -1.247E+03  -2.905E+03  -3.666E+03  -4.101E+03
PARTICLE REYNOLDS NO.   1.218E+00   6.508E+00   1.411E+01   2.303E+01
PARTICLE TEMPERATURE    2.518E+03   2.621E+03   2.706E+03   2.781E+03
PARTICLE DENSITY        1.241E-05   6.951E-05   9.242E-05   2.918E-05
 PARTICLE MOMENTUM FLUX       2.578E+00
***STREAMLINE     9  S=    10.20905
 ** LOCAL GAS PROPERTIES
 U= 2.013E+05  T= 2.448E+03  DENSITY= 2.996E-04  REYNOLDS NO.= 6.670E+21  Y2= 7.370E+00  R2= 7.319E+00
***** PARTICLE PHASE PROPERTIES *****
PARTICLE GROUP              1           2           3           4
DOWNSTREAM VELOCITY     1.892E+05   1.688E+05   1.558E+05   1.450E+05
CROSS-STREAM VELOCITY  -1.672E+03  -3.490E+03  -4.525E+03  -4.881E+03
PARTICLE REYNOLDS NO.   1.221E+00   6.515E+00   1.412E+01   2.306E+01
PARTICLE TEMPERATURE    2.513E+03   2.619E+03   2.706E+03   2.779E+03
PARTICLE DENSITY        1.252E-05   6.950E-05   9.240E-05   2.925E-05
 PARTICLE MOMENTUM FLUX       2.577E+00
***STREAMLINE    10  S=    10.20905
 ** LOCAL GAS PROPERTIES
 U= 2.017E+05  T= 2.439E+03  DENSITY= 2.967E-04  REYNOLDS NO.= 6.626E+21  Y2= 8.191E+00  R2= 8.121E+00
***** PARTICLE PHASE PROPERTIES *****
PARTICLE GROUP              1           2           3           4
DOWNSTREAM VELOCITY     1.894E+05   1.691E+05   1.540E+05   1.431E+05
CROSS-STREAM VELOCITY  -2.145E+03  -4.280E+03  -5.188E+03  -5.649E+03
PARTICLE REYNOLDS NO.   1.232E+00   6.485E+00   1.391E+01   2.300E+01
PARTICLE TEMPERATURE    2.509E+03   2.614E+03   2.698E+03   2.756E+03
PARTICLE DENSITY        1.250E-05   7.013E-05   9.392E-05   2.930E-05
 PARTICLE MOMENTUM FLUX       2.615E+00
***STREAMLINE    11  S=    10.20905
 ** LOCAL GAS PROPERTIES
 U= 2.021E+05  T= 2.436E+03  DENSITY= 2.927E-04  REYNOLDS NO.= 6.579E+21  Y2= 9.018E+00  R2= 8.921E+00
***** PARTICLE PHASE PROPERTIES *****
PARTICLE GROUP              1           2           3           4
DOWNSTREAM VELOCITY     1.898E+05   1.698E+05   1.544E+05   1.440E+05
CROSS-STREAM VELOCITY  -2.616E+03  -5.150E+03  -6.029E+03  -6.638E+03
PARTICLE REYNOLDS NO.   1.233E+00   6.361E+00   1.394E+01   2.255E+01
PARTICLE TEMPERATURE    2.507E+03   2.614E+03   2.699E+03   2.768E+03
PARTICLE DENSITY        1.258E-05   7.063E-05   9.395E-05   2.968E-05
 PARTICLE MOMENTUM FLUX       2.635E+00
***STREAMLINE    12  S=    10.20905
 ** LOCAL GAS PROPERTIES
 U= 2.025E+05  T= 2.432E+03  DENSITY= 2.881E-04  REYNOLDS NO.= 6.511E+21  Y2= 9.868E+00  R2= 9.719E+00
***** PARTICLE PHASE PROPERTIES *****
PARTICLE GROUP              1           2           3           4
DOWNSTREAM VELOCITY     1.901E+05   1.698E+05   1.552E+05   1.436E+05
CROSS-STREAM VELOCITY  -3.051E+03  -5.795E+03  -7.013E+03  -7.594E+03
PARTICLE REYNOLDS NO.   1.230E+00   6.397E+00   1.368E+01   2.261E+01
PARTICLE TEMPERATURE    2.503E+03   2.611E+03   2.692E+03   2.771E+03
PARTICLE DENSITY        1.268E-05   7.161E-05   9.519E-05   2.998E-05
 PARTICLE MOMENTUM FLUX       2.668E+00
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---STREAMLINE=   13  S=    10.20905
 -- LOCAL GAS PROPERTIES
 U= 2.032E+05  T= 2.429E+03  DENSITY= 2.823E-04  REYNOLDS NO.= 6.436E+21  Y2= 1.060E+01  H2= 1.051E+01
----- PARTICLE PHASE PROPERTIES -----
PARTICLE GROUP               1            2            3            4
DOWNSTREAM VELOCITY      1.906E+05    1.703E+05    1.550E+05    1.449E+05
CROSS-STREAM VELOCITY   -3.540E+03   -6.750E+03   -8.142E+03   -8.699E+03
PARTICLE REYNOLDS NO.    1.237E+00    6.293E+00    1.347E+01    2.201E+01
PARTICLE TEMPERATURE     2.502E+03    2.612E+03    2.698E+03    2.769E+03
PARTICLE DENSITY         1.269E-05    7.143E-05    9.624E-05    3.041E-05
 PARTICLE MOMENTUM FLUX        2.718E+00
---STREAMLINE=   14  S=    10.20905
 -- LOCAL GAS PROPERTIES
 U= 2.040E+05  T= 2.425E+03  DENSITY= 2.751E-04  REYNOLDS NO.= 6.361E+21  Y2= 1.152E+01  H2= 1.131E+01
----- PARTICLE PHASE PROPERTIES -----
PARTICLE GROUP               1            2            3            4
DOWNSTREAM VELOCITY      1.911E+05    1.708E+05    1.555E+05    1.461E+05
CROSS-STREAM VELOCITY   -4.378E+03   -8.054E+03   -9.583E+03   -1.046E+04
PARTICLE REYNOLDS NO.    1.251E+00    6.243E+00    1.351E+01    2.214E+01
PARTICLE TEMPERATURE     2.494E+03    2.604E+03    2.687E+03    2.758E+03
PARTICLE DENSITY         1.274E-05    7.210E-05    9.722E-05    3.101E-05
 PARTICLE MOMENTUM FLUX        2.747E+00
---STREAMLINE=   15  S=    10.20905
 -- LOCAL GAS PROPERTIES
 U= 2.052E+05  T= 2.411E+03  DENSITY= 2.660E-04  REYNOLDS NO.= 6.270E+21  Y2= 1.237E+01  H2= 1.211E+01
----- PARTICLE PHASE PROPERTIES -----
PARTICLE GROUP               1            2            3            4
DOWNSTREAM VELOCITY      1.917E+05    1.714E+05    1.567E+05    1.459E+05
CROSS-STREAM VELOCITY   -5.560E+03   -9.408E+03   -1.105E+04   -1.307E+04
PARTICLE REYNOLDS NO.    1.295E+00    6.242E+00    1.324E+01    2.151E+01
PARTICLE TEMPERATURE     2.492E+03    2.603E+03    2.690E+03    2.766E+03
PARTICLE DENSITY         1.277E-05    7.336E-05    1.003E-04    3.245E-05
 PARTICLE MOMENTUM FLUX        2.853E+00
---STREAMLINE=   16  S=    10.20905
 -- LOCAL GAS PROPERTIES
 U= 2.067E+05  T= 2.394E+03  DENSITY= 2.548E-04  REYNOLDS NO.= 6.192E+21  Y2= 1.324E+01  H2= 1.291E+01
----- PARTICLE PHASE PROPERTIES -----
PARTICLE GROUP               1            2            3            4
DOWNSTREAM VELOCITY      1.926E+05    1.721E+05    1.572E+05    1.461E+05
CROSS-STREAM VELOCITY   -7.049E+03   -1.201E+04   -1.494E+04   -1.682E+04
PARTICLE REYNOLDS NO.    1.353E+00    6.282E+00    1.323E+01    2.145E+01
PARTICLE TEMPERATURE     2.479E+03    2.582E+03    2.672E+03    2.742E+03
PARTICLE DENSITY         1.279E-05    7.535E-05    1.059E-04    3.563E-05
 PARTICLE MOMENTUM FLUX        3.002E+00
---STREAMLINE=   17  S=    10.20905
 -- LOCAL GAS PROPERTIES
 U= 2.079E+05  T= 2.362E+03  DENSITY= 2.414E-04  REYNOLDS NO.= 6.123E+21  Y2= 1.414E+01  H2= 1.373E+01
----- PARTICLE PHASE PROPERTIES -----
PARTICLE GROUP               1            2            3            4
DOWNSTREAM VELOCITY      1.936E+05    1.736E+05    1.580E+05    1.473E+05
CROSS-STREAM VELOCITY   -8.654E+03   -1.595E+04   -2.007E+04   -2.462E+04
PARTICLE REYNOLDS NO.    1.375E+00    6.171E+00    1.313E+01    2.129E+01
PARTICLE TEMPERATURE     2.467E+03    2.584E+03    2.678E+03    2.763E+03
PARTICLE DENSITY         1.294E-05    8.180E-05    1.245E-04    4.788E-05
 PARTICLE MOMENTUM FLUX        3.503E+00
---STREAMLINE=   18  S=    10.20905
 -- LOCAL GAS PROPERTIES
 U= 2.133E+05  T= 2.311E+03  DENSITY= 2.321E-04  REYNOLDS NO.= 6.033E+21  Y2= 1.504E+01  H2= 1.453E+01
----- PARTICLE PHASE PROPERTIES -----
PARTICLE GROUP               1            2            3            4
DOWNSTREAM VELOCITY      1.959E+05    0.           0.           0.
CROSS-STREAM VELOCITY   -8.134E+03    0.           0.           0.
PARTICLE REYNOLDS NO.    1.573E+00    0.           0.           0.
PARTICLE TEMPERATURE     2.435E+03    0.           0.           0.
PARTICLE DENSITY         1.344E-05    0.           0.           0.
 PARTICLE MOMENTUM FLUX        2.548E-01
---STREAMLINE=   19  S=    10.20905
 -- LOCAL GAS PROPERTIES
 U= 2.140E+05  T= 2.199E+03  DENSITY= 2.618E-04  REYNOLDS NO.= 5.887E+21  Y2= 1.580E+01  H2= 1.522E+01
----- PARTICLE PHASE PROPERTIES -----
PARTICLE GROUP               1            2            3            4
DOWNSTREAM VELOCITY      0.           0.           0.           0.
CROSS-STREAM VELOCITY    0.           0.           0.           0.
PARTICLE REYNOLDS NO.    0.           0.           0.           0.
PARTICLE TEMPERATURE     0.           0.           0.           0.
PARTICLE DENSITY         0.           0.           0.           0.
 PARTICLE MOMENTUM FLUX        0.
---STREAMLINE=   20  S=    10.20905
 -- LOCAL GAS PROPERTIES
 U= 2.101E+05  T= 2.291E+03  DENSITY= 3.125E-04  REYNOLDS NO.= 5.871E+21  Y2= 1.667E+01  H2= 1.585E+01
----- PARTICLE PHASE PROPERTIES -----
PARTICLE GROUP               1            2            3            4
DOWNSTREAM VELOCITY      0.           0.           0.           0.
CROSS-STREAM VELOCITY    0.           0.           0.           0.
PARTICLE REYNOLDS NO.    0.           0.           0.           0.
PARTICLE TEMPERATURE     0.           0.           0.           0.
PARTICLE DENSITY         0.           0.           0.           0.
 PARTICLE MOMENTUM FLUX        0.
 BOUNDARY OF PARTICLE PHASE AT S=   10.61200   1.479E+01   1.417E+01   1.376E+01   1.362E+01
 BOUNDARY OF PARTICLE PHASE AT S=   11.01090   1.496E+01   1.431E+01   1.389E+01   1.353E+01
 BOUNDARY OF PARTICLE PHASE AT S=   11.41900   1.513E+01   1.447E+01   1.403E+01   1.366E+01
 BOUNDARY OF PARTICLE PHASE AT S=   11.82986   1.530E+01   1.462E+01   1.417E+01   1.378E+01
 BOUNDARY OF PARTICLE PHASE AT S=   12.25150   1.547E+01   1.476E+01   1.431E+01   1.391E+01
 BOUNDARY OF PARTICLE PHASE AT S=   12.67466   1.564E+01   1.493E+01   1.445E+01   1.405E+01
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APPENDIX C

SAMPLE OUTPUT - EXPLANATIONS

APPENDIX C

SAMPLE OUTPUT - EXPLANATIONS

The first page of output contains all the input data on Cards 1-5 and 7, followed by the species identification data (Card 9) and the distributions of properties along the initial orthogonal surface. The units of each variable are identical with those used for the input data. These are followed by the axis location and the nozzle wall contour.

The standard printed output at each value of KP (Card 5, Cols. 11-15) or DXLSS (Card 3, Cols. 11-22) gives properties for each streamtube, from K (streamtube index) = 2 to K = KMAX. In addition to the usual output* i.e. X, R, PHI, T, P, U, the following properties are printed:

	MA	Mach number
	DELY	streamtube width (cm)
	H	enthalpy (cal/g)
	HT	stagnation enthalpy (cal/g)
	TAW	shear stress at tube interface (dynes/cm^2)
	Q	heat flux at tube interface (cal/cm^2-sec)
	PT	dynamic pressure (atm)
	RHO	density (g/cm^3)
	SX	distance along streamtube (cm)
	SUMDOT	total mass flow bounded by streamtube (g/sec)
	C	species mass fraction
	X	species mole fraction
	WDOT	species production rate (g/cm^3 sec)
only for viscous flows	FI	total mass flow of species up to present streamtube (g/sec)
	ZJ	species flux at tube interface

* X and R refer to the coordinates of the outer boundary of streamtube while the flow properties are average values across the streamtube.

Boundary layer parameters, if computed, are printed between the tube properties and the composition data in the last streamtube (at downstream print stations). The following parameters are printed:

RES	Reynolds number based on distance along wall
DELTAI	boundary layer thickness (incompressible)
THETAI	momentum thickness (incompressible)
CFI	skin friction coefficient (incompressible)
UFI	friction velocity (incompressible)
DISP	displacement thickness
DELTAC	boundary layer thickness
THETAC	momentum thickness
CFC	skin friction coefficient
H12	shape factor (= DISP/THETAC)
QWALL	heat flux at wall (cal/cm^2-sec)
TAUWALL	shear stress at wall ($dynes/cm^2$)
U/UE	B.L. velocity profile (UE = velocity in last tube)
T/TE	B.L. temperature profile (TE = temperature in last tube)
Y/DEL	location in B.L. (DEL ≡ DELTAC)

If IPART = 1, particle properties are printed; first, a NAMELIST of the input data on Cards 15 through 19 (and 20 through 23 for NC = 0), followed by the initial particle properties in each streamtube. The standard particle print gives the downstream and cross-stream velocity, temperature, Reynolds number and particle cloud density for each particle group and total particle momentum flux, for each streamtube. Since, typically, the limiting particle streamlines are within streamtube KMAX the outer tubes will contain no particles Limiting particle streamlines are noted as, 'BOUNDARY OF PARTICLE PHASE AT S = X. XXXXX', followed by the radial position of the limiting particle streamline for each particle group. If the particles are initially in the liquid phase the program will print where they start to solidify.

APPENDIX D

FORTRAN LISTING

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      PROGRAM FNOZ(INPUT,OUTPUT,TAPE5,TAPE5=INPUT,TAPE6=OUTPUT,TAPE7,       MAIN        2
     1  TAPE8,TAPE9,TAPE10)                                                  MAIN        3
C     ****************************************************************** MAIN        4
C     **              FULLY COUPLED NOZZLE PROGRAM                       ** MAIN        5
C     **          AERONCHEM RESEARCH LABORATORIES, INC.                  ** MAIN        6
C     **                  PRINCETON, NEW JERSEY   08540                  ** MAIN        7
C     ****************************************************************** MAIN        8
      COMMON A(25,7)    ,AA(40)      ,ALFA(25,25),ALPHAN     ,ALPHAP     A           2
     1       ,ATOL       ,BETAP       ,BMIX       ,C11(25)    ,C(25,40)   A           3
     2       ,C12(25)    ,C2(25,40)   ,CABAR(25)  ,CBBAR(25)  ,CP         A           4
     3       ,CPS(25)    ,CPSH        ,CSH(25)    ,CSH1(25)   ,CSTREM(25) A           5
     4       ,MXSTRM     ,D2IN(25,25),DEFF(25)    ,D2EFF(25)  ,DELTA      A           6
     5       ,D11        ,DFLSS(40)   ,DELS       ,DELSU      ,DLS(40)    A           7
     6       ,DIM(25,25) ,D12         ,DELY(40)   ,D13        ,DPDY(40)   A           8
     7       ,D14        ,DPHIUS(40)  ,EPCON                               A           9
     8       ,EPSLOP     ,EXTRA(50)   ,FSTEP      ,FMAX       ,GRAD       A          10
     9       ,H11        ,H(40)       ,HH         ,HJ         ,HPM(25)    A          11
     *       ,H2PM(25)   ,HSPM(25)    ,ICONST     ,ICOUNT     ,IDENT(25)  A          12
     1       ,IERROR     ,IEXTRA(50)  ,IFLAG      ,IKIND                  A          13
     2       ,IPTOC      ,ISHOCK      ,ITYPE      ,IPO                    A          14
     3       ,IDIFF      ,R           ,RAY        ,RAYS       ,RAY2       A          15
     4       ,KLO        ,KMAX                                            A          16
     5       ,KUP        ,KR          ,LL         ,LPLANE     ,MA         A          17
     6       ,MASH       ,MCOI        ,MMAX       ,MUO        ,MU         A          18
     7       ,MU2        ,MUS         ,MR         ,MR2        ,MRSH       A          19
     8       ,NBOUND     ,NOS         ,NITER      ,NMAX       ,NN         A          20
      COMMON NUCASE     ,OMEGA(25)   ,P11        ,P(40)      ,P12        A          21
     1       ,P2(40)                  ,PB(50)     ,PABAR      ,PBBAR      A          22
     2       ,PHS        ,P15         ,PHI(40)                ,PHIN(50)   A          23
     3       ,PHISH1     ,PHSTRM                  ,PHIW(50)   ,P16        A          24
     4       ,PHI2(40)   ,PHIUS       ,P1         ,PR(25)     ,PSH        A          25
     5       ,PSH1       ,PS1         ,PSTREM                 ,PW(50)     A          26
     6       ,Q11        ,Q(40)       ,QXTR1      ,QXTR2                  A          27
     7       ,QW(50)     ,R11         ,R(40)                  ,RB(50)     A          28
     8       ,RHS        ,R13         ,RHAR(40)   ,R14        ,R2(40)     A          29
     9       ,RCON       ,R15         ,RE(40)     ,RESH       ,R16        A          30
     *       ,RHO(40)    ,R17         ,RHO2(40)   ,RHS(25)    ,RHSEN      A          31
     1       ,RHSHCK     ,RHABAR      ,RHOBAR     ,RU         ,RSH        A          32
     2       ,RSTREM     ,RV          ,R19        ,RW(100)    ,S          A          33
     3                   ,SP(50)      ,SC(25)                 ,SW(50)     A          34
     4       ,S13        ,ST(40)      ,T11        ,T(40)      ,T12        A          35
     5       ,T2(40)     ,TABAR       ,TBBAR      ,T0(25)     ,T14        A          36
     6       ,TAR(40)    ,TXTR1       ,TXTR2      ,TOL        ,TSH        A          37
     7       ,TSH1       ,TSTREM                  ,TW(50)     ,TWS        A          38
     8       ,TS         ,U11         ,U(40)      ,U12        ,U2(40)     A          39
      COMMON UXTR1      ,UXTR2       ,U14        ,UBAR(40)   ,USH        A          40
     1       ,USH1       ,USTREM                  ,UW(50)     ,UWS        A          41
     2       ,X11        ,X(40)       ,X12        ,X2(40)                 A          42
     3       ,XP(50)     ,XBS         ,XABAR(25)  ,XBBAR(25)  ,X15        A          43
     4       ,XS(25,40)  ,XSH         ,XSTREM                 ,XW(50)     A          44
     5       ,ZPER(40)                ,Y11        ,Y(40)      ,Y12        A          45
     6       ,Y2(40)     ,YABAR       ,YBBAR      ,ZA(25)     ,Z11(25)    A          46
     7       ,ZJ(25,40)  ,ZPR         ,SZA        ,RZSH       ,XZSH       A          47
     8       ,FA(2,40)   ,FR(2,40)    ,FPHI(2,40) ,FP(2,40)   ,FT(2,40)   A          48
     9       ,FU(2,40)   ,INDL(2,40)  ,INDR(2,40) ,FC(2,40,25),CAND1      A          49
     *       ,R          ,R                                               A          50
      DIMENSION IP(20)                                                    MAIN       10


      DIMENSION G(2),GG(2,2),A1(2)                                        MAIN       11
      REAL   RAY        ,RAYS(25)    ,RAY2       ,RR         ,MIXT(40)    MAIN       12
     *       ,MA(40)     ,MU          ,MUS(25)    ,MUV(25)    ,MU2        MAIN       13
     *       ,MR(25)     ,MR2         ,MASH       ,MASH1      ,MASH       MAIN       14
     * ,     MAP                                                          MAIN       15
      COMMON/P1/BMOPV(8), BMOMP(8),ENERP1(8),REP(40,8),V(40,8),W(40,8),  MAIN       16
     1V2(40,8), W2(40,8), TBODY(8), TP(40,8), TP2(40,8), WP(8),           MAIN       17
     2RHP(40,8), RHP2(40,8) ,ENEP2(8),RRL(8),UM(40)                       MAIN       18
     3,VOLP(8),ALF(8),HC(8),DFNG(40,8),ICOND(40,8)                        MAIN       19
      COMMON/P12/PPP,PPL,GAMA,CP1,PR,RPL,RRR,DRDSP(8)                     MAIN       20
       COMMON/P13/LL,CS,IPS,RMSS,RI,RIMAX,SIG,EP,IPART,IKINE,IR(40)       MAIN       21
     1 ,SUPP,SUPPV,SUPPE                                                  MAIN       22
      COMMON/MAINSH/ ICOUNT,KINT                                          MAIN       23
      COMMON/IROGSI/ IRUUSH                                               MAIN       24
      COMMON/CHEM1/ ZID(5), IRR(40),IRT(40),RC(40,3),IRRR(40,5),          MAIN       25
     1 AV,CM(26,26),PI(26),API(26),                                       MAIN       26
     2 PR(20),CUT(26,40),CST(26),CX(26)                                   MAIN       27
      COMMON/INIT/XLX,IXI,REX                                             MAIN       28
      COMMON/WMEET/WMEF(40)                                               MAIN       29
      COMMON/INPUT/ITP,XU,YO,FRAC  ,APL                                   MAIN       30
      COMMON/SHOUT/ XSHR,RSHR,PS1R,PSHR,TSHR,USHR,CSHR(25)                MAIN       31
      COMMON/IRSHOK/ RIL,IHO,UDU,PMID,CIN(25)                             MAIN       32
      COMMON/ALP/XIM                                                      MAIN       33
      COMMON/AYZ/IAYZ,JAYZ                                                MAIN       34
      DOUBLE PRECISION ERROR (3)                                          MAIN       35
      EQUIVALENCE (MUVF,IEXTRA(15))                                       MAIN       36
      EQUIVALENCE (RALARM, IEXTRA(20))                                    MAIN       37
      DATA ERROR / 8HFAILS,8HEPDRY,8HSTEP /                               MAIN       38
C     SETTING UP THE PROBLEM                                              MAIN       39
C     REVISED SUBSCRIPTS (ZEROS DELETED)                                  MAIN       40
      WRITE(6,150)                                                        MAIN       41
  150 FORMAT(1H1,////////////81X,29HFULLY COUPLED NOZZLE FLOW PROGRAM,/// 25SEPT      1
     1 80X,40HAERONCHEM RESEARCH LABORATORIES, INC.,//65X,                25SEPT      2
     2 29HPRINCETON, NEW JERSEY 08540)                                    25SEPT      3
      IAY=81                                                              MAIN       46
      JAY=40                                                              MAIN       47
      IDATA=0                                                             MAIN       48
      READ(5,50) NDATA                                                    MAIN       49
  201 CONTINUE                                                            MAIN       50
      READ (5,9996) (IC(I), I=1,20)                                       MAIN       51
      WRITE (6,9997) (IC(I),I=1,20)                                       MAIN       52
 9996 FORMAT (20A4)                                                       MAIN       53
 9997 FORMAT (1H1,20A4)                                                   MAIN       54
      WRITE(6,51) NDATA                                                   MAIN       55
```

```
   51 FORMAT (1H0,/10X,17HNO. OF DATA SETS    ,I5)
      DO 5 I=1,NT
    5 A(I,1)=0.0
      KALARM=0
      KOUNT=0
      KINT=0
      LL=-1
      READ (5,50) FSEC,DALSS,ALMAX,ALMOD,IMO,NNT
      WRITE (6,52) FSEC,DALSS,ALMAX,XLMOD,IMO,NNT
   50 FORMAT(1I0,3E12.5,2I2)
   52 FORMAT (1H ,4X,5HNSEC=,I5,4X,6HDALSS=,1PE10.3,4X,6HALMAX=,E10.3,
     *  4X,6HALMOD=,E10.3,4X,4HIMO=,I5,4X,4HNNT=,I5///)
      ALMX=DALSS


      FSEC=NSEC
      TOLD=0.
      ANG=1.
      ALM=1.E10
  100 CALL PUTIN
      DO105 I=1,NMAX
  105 HEE(I)=0.0
      IF (IPART.NE.0) CALL PPUTIN
      IF (INIKF.NE.0) CALL CPUTIN(IDENT,INIKF,NDS)
      IF(ININD.LT.3.OR.IN1.NE.0) GO TO 21
      CPM=0.0
      ZMM=0.0
      DO109 I=1,NDS
      ZMM=ZMM+CSTREM(I)/MP(I)
  109 CPM=CPM+CSTRE(I)*A(I,3)
      ZMM=1.0/ZMM
      EMF=0STMEM*SQRT((CPM*/MM-R(ON)/(CPM*STREM*RU))
      PE=0.0
      EM=0.0
      DO25 I=2,NMAX
      EM=EM+MA(I)
   25 PE=PE+P(I)
      EM=EM/(NMAX-1)
      PE=PE/(NMAX-1)
      IF(IPART.EQ.0) GO TO 25
      NMG=0.0
      PGM=0.0
      DO24 I=2,NMAX
      NMG=NMG+NMU(I)
      DO24 J=1,NPG
      K=I-1
   24 PGM=PGM+NMP2(K,J)
      PGM=PGM/NMG
      GO TO 26
   25 PGM=0.0
      WRITE(6,262) PE,PSTREM,GAMA,EMF
   26 ALM=XNEXX.09*EM*SQRT(GAMA*PE/PSTREM)/(EMF**.25*(1.+.197*EM**1.45*P
     *GM**.65))**2.
      WRITE(9,5) ALMO
    5 FORMAT(E12.5)
      IF(ININD.LT.3) ALM=1.E10
      IF(IMO.NE.0) ALM=ALMOD
      WRITE(6,28) ALMO
   28 FORMAT(2X,5HALM=,E12.5)
      GO TO 100
   21 IF(ISHOCK.EQ.1) GO TO 101
      PENF=PSTRE
      GAMM=CPM/(CPM-(RU/ZMM))
      EMFE=MA(NMAX)
      SEMA2=SQRT(EMFE**2-1.0)
      EMF2=EMF**2
      TMG=EMI(NMAX)
      PE=P(NMAX)
      EMM=EMFE*(PE/PENF**.5)**((GAMA-1.)/GAMA)
      TL=1.E-6*EMB
      C1=SQRT((GAMA+1.)/(GAMA-1.))
      C3=GAMA/(GAMA-1.)


      THETA(1)=ATAN(SEMA2/C1)-ATAN(SEMA2)-THN
      DO 106 II=1,100
      EMM2=EMM**2
      SQEMM=SQRT(EMM2-1.0)
      ZTA=C1*ATAN(SQEMM/C1)-ATAN(SQEMM)+THE
      PP=PE*(1.+(GAMA-1.)/2.*EME**2)**C3/(1.+(GAMA-1.)/2.*EMM2)**C3
      ETA=ASIN (SQRT(1.+(GAMM+1.)/(2.*GAMM)*(PP/PENF-1.))/EMF)
      SIGMTA=SIN(ETA)
      SNTA2=SINETA**2
      COSNTA=COS(ETA)
      FS=((EMF*SINETA)**2-1.)/TAN(ETA)/((GAMM+1.)/2.*EMF2-(EMF*SINETA)
     1    **2+1.) -TAN(ZTA)
      F=((GAMM+1.)/2.*EMF2  -(EMF*SINETA  )**2+1.)
      ...
      ...
      ...
      ...
     1A/(SNNTA2     )**2.*(EMF*COSNTA  )**2)*SNTA  /SNGM-((EMF*SINETA  )*
     2*2-1.)**2.*(EMF*COSNTA  )**2*ETA/SNGM**2)
      IF (ABS(F) .LT. TL ) GO TO 107
      EMM=EMM-F/FS
  106 CONTINUE
      WRITE (6,108)    ...
  108 FORMAT(1H0,27HITERATION DOES NOT CONVERGE ,10X,E12.5)
  107 CONTINUE
```

```
      PSI=BTA
      PS=PP
      ASHO=(AMAX)
      ASHO=(AMAX)
      GPI=(GAMMA+1.)/(GAMMA-1.)
      TSHO=TSTHE*(PP/PENF+GM1)
     1 (    GP1*PENF/PP)
      U=(PP/PENF+GP1)/(GM1*PP/PENF+1.)*USTHE*SINBTA
      LSH=SQRT((USTHE*COSBTA  )**2+UN**2)
  100 CONTINUE
  101 AMA=0 AMA*2
      ICONT=0
      INTG=HALPHAP
      KUCASE=0
      ITER=0
      LL=0
      S=0.0
      XLR=1.0E5
      SPDT=0.0
      IAR=P
      LIAT=0
      SLEL=(1.0E-8)**2
C     ESTABLISHING STABLE STEP SIZE
  200 TIME=0.0
      TLEFT=SEC-TIME
      TSTEP=TIME-TOLD
      IF (LL.LE.0) GO TO 205
      IF (TSTEP.GT.(0.5*TLEFT)) GO TO 210
  205 TOLD=TIME
      CALL STABLE
      NCOUNT = 0
      ICOUNT=0


      MOVE=0
      IF((LL.GT.LPLANE).OR.(X(2).GT.XLMAX)) GO TO 210
      IF(X2(2).GE.XLPO.AND.ISHOCK.NE.0) GO TO 206
      IF((IMO.NE.0).OR.(X2(2).LT.XLMD)) GO TO 250
C     TAKE OUT
      GO TO 303
C     TAKE OUT
  300 GAMMA=GAMA
      GAMMA=GAMA
      PSHI=P2(2)
      TSHI=T2(2)
      USHI=U2(2)
      MASHI=MA(2)
      MASH=ZMAR(2)
      HISH(2)
      ITER=0
      DELPHI=-PHI2(2)
      IF(ICONST) 3500,3400,3500
 3400 H1=-(MASHI**2+2.0)/(MASHI**2)-GAMMA*SIN(DELPHI)**2
      H2=(2.0*MASHI**2+1.0)/(MASHI**4)
      H3=H2+((GAMMA+1.0)**2/4.0+(GAMMA-1.0)/(MASHI**2))*SIN(DELPHI)**2
      F=(COS(DELPHI))**2/(MASHI**4)*(-1.0)
      ZETA=(1.0/MASHI*SIN(DELPHI))**2
 2700 ITER=ITER+1
      GG=ZETA**3+H1*ZETA**2+H2*ZETA+H3
      DGDZ=3.0*ZETA**2+2.0*H1*ZETA+H2
      DLZETA=-GG/DGDZ
      IF(ABS(DLZETA/ZETA)-TOL) 2100,2005,2005
 2005 IF (ITER-NITER) 2900,2900,2000
 2900 ZETA=ZETA+DLZETA
      GO TO 2700
 2000 WRITE (6,2050)
 2050 FORMAT(27HITERATIONS FOR ZETA FAILED)
      CALL PODER (A(1,1),N,5)
C     DETERMINATION OF SHOCKED GAS PROPERTIES
 2100 CONS=CP  *TSHI+USHI**2/(2.0*AMJ)
      PS =(2.0*GAMMA*MASHI**2*ZETA-GAMMA+1.0)/(GAMMA+1.0)*PSHI
      TS =(PS /PSHI)*((GAMMA-1.0)*MASHI**2*ZETA+2.0)
      TS =TS /((GAMMA+1.0)*MASHI**2*ZETA)*TSHI
      US =SQRT(2.0*AMJ*(CONS-CP  *TS ))
      THS=ASIN(SQRT(ZETA))
      IF (IMOUSH.NE.0) WRITE (6,2220) PS  ,TS  ,US  ,ZETA
 2220 FORMAT (1X,2HPS,1PE11.4,3X,5HTS= ,1PE11.4,3X,5HUS= ,1PE11.4,
     *3X,5HZETA=,1PE11.4)
       GO TO 6000
 3500 THS=PHI2(2)*(GAMMA+1.)/2.000
      TS=2.*TSHI
 3200 E=MASHI**2
      F=GAMMA+1.
      TERM1=GAMMA*F*DELPHI/SQRT(E-1.)
      TERM2=TERM1*(F*E**2-4.*(E-1.))*DELPHI/(4.*(E-1.)**(3./2.))
      IF (ITER2.GT.0.001*TERM1) GO TO 2250
      TERM3=TERM1*(F*E**2*E**4/32.-(7.+12.*GAMMA-3.*GAMMA**2)*E**3+.75*F*E
     ***2-E+2./3.)*DELPHI**2/(E-1.)**3
      X=1.+TERM1+TERM2+TERMS
      ZETA=(F*X+F-2.)/(2.*GAMMA*E)
      GO TO 2100


 2250 ITER=ITER+1
      H2=0.0
      CZ=C.0
      DO 2300 I=1,ICS
      DO 2300 J=1,NN
      H2=H2+A(I,J)*C2(I,2)*TS**(J-2)
 2300 CZ=CZ+CONST(J-2)*A(I,J)*TS**(J-3)*C2(I,2)
```

```
      SI1=SIN(THB)                                                    MAIN  247
      SI0=SIN(THB-DELFPI)                                             MAIN  248
      CO1=COS(THB)                                                    MAIN  249
      CO0=COS(THB-DELFPI)                                             MAIN  250
      TA1=SI1/CO1                                                     MAIN  251
      TA0=SI0/CO0                                                     MAIN  252
      CO12=CO0*CO1                                                    MAIN  253
      CO2=CO0*CO0                                                     MAIN  254
      G(1)=[illegible]                                                MAIN  255
      G(2)=[illegible]                                                MAIN  256
     *[illegible](1.-TAU/TA1))                                        MAIN  257
      [illegible]                                                     MAIN  258
      [illegible]                                                     MAIN  259
      [illegible]=PSH1/TA1                                            MAIN  260
      [illegible]                                                     MAIN  261
     *[illegible](1.-TAU/TA1)[illegible]  (1.-TAU/TA1))               MAIN  262
      IF (IPRDBSW.EQ.0) WRITE (6,2951) G(1),G(2),TS,THB,UGL(1,1),UGL(1,2)  MAIN  263
     *,UGL(2,1),UGL(2,2)                                              MAIN  264
 2950 FORMAT (12X,6E12.5)                                             MAIN  265
      TTTS=.0                                                         MAIN  266
      CALL [illegible](2,2,TOUL,G,TTT,AA,J)                           MAIN  267
      GO TO (2600,2000,2500),J                                        MAIN  268
 2000 WRITE (6,2005)                                                  MAIN  269
 2005 FORMAT (42H1SIGNIFICANT OVERFLOW IN SUBROUTINE SHOCK)           MAIN  270
      GO TO 2510                                                      MAIN  271
 2500 WRITE (6,2505)                                                  MAIN  272
 2505 FORMAT (42H1SINGULAR DETERMINANT IN SUBROUTINE SHOCK)           MAIN  273
 2510 CALL [illegible](A(1,1),N,1)                                    MAIN  274
      CALL EXIT                                                       MAIN  275
 2600 DO 2650 I=1,2                                                   MAIN  276
 2650 XX(I)=UGL(3,I)                                                  MAIN  277
      IF (ABS(XX(1)/TS)-TOL ) 2800,2705,2705                          MAIN  278
 2705 TS=TS+XX(1)                                                     MAIN  279
      THB=THB+XX(2)                                                   MAIN  280
      IF (ITER-NIT(K)) 3200,3200,2750                                 MAIN  281
 2750 WRITE (6,2050)                                                  MAIN  282
      GO TO 2510                                                      MAIN  283
 2800 IF (ABS(XX(2)/THB)-SLOT(TOL)) 2905,2700,2700                    MAIN  284
 2905 CS =[illegible]                                                 MAIN  285
      PS = [illegible]                                                MAIN  286
      ZETA=SIN(THB)**2                                                MAIN  287
 4000 WRITE(7,220)  X2(1),H2(1),THB,PS,TS,US                          MAIN  288
      WRITE (6,5000) X2(1),H2(1),THB,PS,TS,US                         MAIN  289
      WRITE(7,230)  (C2(I,2),I=1,NOS)                                 MAIN  290
      WRITE (6,5001) (C2(I,2),I=1,NOS)                                MAIN  291
 5000 FORMAT(1H ,/5X,[illegible] REFLECTED SHOCK CONDITIONS,/5X,      MAIN  292
     * 2HXS,1PE10.3,5X,2HHS,E10.3,5X,[illegible],E10.3,5X,[illegible],E10.3,  MAIN  293
     1 5X,5HTSHKS,E10.3,5X,5HUSHKS,E10.3)                             MAIN  294
 5001 FORMAT (1H ,/5X,30HSPECIES MASS FRACTIONS  [illegible] ,/5X,8(1PE10.3,  MAIN  295
     * 5X))                                                           MAIN  296
C     TAKE OUT                                                        MAIN  297
  305 CONTINUE                                                        MAIN  298
      ITER=1                                                          MAIN  299
      ISW(K)=1                                                        MAIN  300
      [illegible]=0                                                   MAIN  301
      [illegible] ASIN(1./[illegible](2)))                            MAIN  302
      IF [illegible]                                                  MAIN  303
      [illegible]                                                     MAIN  304
 1120 [illegible]                                                     MAIN  305
      [illegible]                                                     MAIN  306
      [illegible]                                                     MAIN  307
      [illegible]                                                     MAIN  308
      [illegible]                                                     MAIN  309
      WRITE (6,[illegible])                                           MAIN  310
      [illegible]                                                     MAIN  311
      [illegible]                                                     MAIN  312
      [illegible]                                                     MAIN  313
      [illegible]                                                     MAIN  314
 [illegible]                                                          MAIN  315
      IF [illegible]                                                  MAIN  316
 [illegible]                                                          MAIN  317
      GO TO [illegible]                                               MAIN  318
 [illegible]                                                          MAIN  319
      [illegible]                                                     MAIN  320
 [illegible]                                                          MAIN  321
      IF [illegible]                                                  MAIN  322
 [illegible]                                                          MAIN  323
      GO TO [illegible]                                               MAIN  324
 [illegible]                                                          MAIN  325
 [illegible]                                                          MAIN  326
      [illegible]                                                     MAIN  327
      WRITE [illegible]                                               MAIN  328
      IF [illegible]                                                  MAIN  329
 [illegible] FORMAT [illegible]                                       MAIN  330
 [illegible] FORMAT [illegible]                                       MAIN  331
     1 [illegible]                                                    MAIN  332
 [illegible]                                                          MAIN  333
      [illegible]                                                     MAIN  334
      [illegible]                                                     MAIN  335
      GO TO [illegible]                                               MAIN  336
 [illegible]                                                          MAIN  337
      WRITE [illegible]                                               MAIN  338
 [illegible] FORMAT [illegible]                                       MAIN  339
      [illegible]                                                     MAIN  340
      WRITE [illegible]                                               MAIN  341
      WRITE [illegible]                                               MAIN  342
 [illegible] FORMAT [illegible]                                       MAIN  343
 [illegible] CONTINUE                                                 MAIN  344
      [illegible]                                                     MAIN  345
      [illegible]                                                     MAIN  346
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```
      WRITE(7,221)X(1),H(1),X11,H(1),X(KMAX),H(KMAX),X22,H(KMAX)
  221 FORMAT(2E12.5/2E12.5/2E12.5/2E12.5)
      IF(IPINW.LT.4) GO TO 267
      WRITE(7,220)X(KMAX),H(KMAX),PS1,PSN,TSN,USN
      WRITE(7,230)(CSTHEN(I),I=1,NOS)
      WRITE(7,220) XSTHEN,RSTHEN,PHSTAN,PSTHEN,TSTHEN,USTHEN
      WRITE(7,230) ((STHEN(I),I=1,NOS)


      IF(ITYPE.NE.3) GO TO 267
      WRITE(7,220) XSMM,RSMM,PS1M,PSMM,TSMM,USMM
      WRITE(7,230)  ((SMM(I),I=1,NOS)
      WRITE(7,220) XUO,RUO,PHUO,PUO,TUO,UUO
      WRITE(7,230)  ((UO(I),I=1,NOS)
      GO TO 267
  266 IF(IMI.EQ.0) GO TO 211
      WRITE(7,220)   X2(1),R2(1),PHI2(1)
      K=2
      DO 267 K=2,KMAX
      TLSTZ(K)=1.E-6
      RMUXY=.15
C     TAKE OUT
      RMUXY=(GAMA-1.)/(GAMA+1.)
C     TAKE OUT
      RMUY1=RMU2(K)/RMUXY
      RMUY=RMU2(K)/RMUXY
      DO 40 II=1,100
      PY=P2(K)+RMU2(K)*U2(K)**2*(1.-RMUXY)/BETAP
      HY=H(K)+U2(K)**2/(2.*HJ)*(1.-RMUXY**2)
      TY=T2(K)*PY/P2(K)*RMUXY
C     TAKE OUT
      GO TO 46
      DO 41 III=1,100
      DHYT=0.0
      HYT=0.0
      DO 42 I=1,NOS
      DO 42 JJ=1,NN
      HYT=HYT+A(I,JJ)*TY    **(JJ-2)*C2(I,K)
   42 DHYT=DHYT+A(I,JJ)*FLOAT(JJ-2)*TY    **(JJ-3)*C2(I,K)
      D=HYT-HY
      IF(ABS(D).LT.TL) GO TO 43
      TY=TY-D/DHYT
   41 CONTINUE
      WRITE(6,44) II,K,HY,HYT ,DHYT
      STOP
   43 RMUY1=PY*Z/PRR(K)/HY/TY
      IF((ABS(RMUY1/RMUY)-1.) .LT. .001) GO TO 46
      RMUY=(RMUY1+RMUY)*.5
      RMUXY=RMU2(K)/RMUY
   40 CONTINUE
      WRITE (6,44) II,K,RMUY,RMUY1,RMUXY
   44   FORMAT(2X,26HITERATIONS DO NOT CONVERGE,/2X,3HIT=,I3,2X,2HK=,I3,
     42X,3HHY=,E12.5,2X,5HH(K)=,E12.5,2X,5HDHYT=,E12.5)
   46 UY=U2(K)*RMU2(K)/RMUY1
      WRITE(7,45) X2(1),R2(K),PY,TY,UY
      WRITE(6,45) X2(1),R2(K),PY,TY,UY
      WRITE(7,230)    (C2(I,K),I=1,NOS)
   45 FORMAT(2E12.5,12X,3E12.5)
  267 CONTINUE
      K=K
  267 IF (IPART.EQ.0) GO TO 286
      L=1
      NP=NHL(1)
      IF (NPG.LE.1) GO TO 285
      DO 281 J=2,NPG
      IF (KK.LT.NPG(J)) NP=NHL(J)


  281 CONTINUE
  285 CONTINUE
      WRITE(7,282) FFF,FFG,CL,CS, TRAN,A1,PC
      WRITE(7,282) RMSS,SIG,EP      ,TPS    ,OMI
      WRITE(7,283) NPG,NL
      WRITE(7,283) (NPL(J),J=1,NPG)
      WRITE(7,282) (HP(J),J=1,NPG)
      DO 284 K=1,NP
      WRITE(7,282) (X(K,J),J=1,NPG)
      WRITE(7,282) (Y(K,J),J=1,NPG)
      WRITE(7,282) (TP(K,J),J=1,NPG)
      WRITE(7,282) (RHP(K,J),J=1,NPG)
      WRITE(7 283)(ILCND(K,J),J=1,NPG)
      WRITE(7,282)(DEKG(K,J),J=1,NPG)
  284 CONTINUE
      WRITE(7,282) (TPFLV(J),J=1,NPG)
      WRITE(7,282) (CNTSP(J),J=1,NPG)
  282 FORMAT(8E10.5)
  283 FORMAT(8I5)
  286 CONTINUE
      IF(X2(2).GE.XLMT.AND.IRMUCK.NE.0) GO TO 212
      ICATA=ICATA+1
      IF (ICATA.LT.ICATA) GO TO 281
      CALL EXIT
  212 IPLAP=ICLL+1
  211 XL=X1,E20
  250 IFLAG=0
      IF(DELS.LT.SEPT) GO TO 4961
      L=1
      IF (ICOUNT    ) 261,270,260
  260 SBS=DELSO
      DELSO=.SOPELS
```

```
  875 AA(K)=PI*(R2(K)+R2(K-1))**DELTA*DELY(K)
      Y2(K)=Y2(K-1)+DELY(K)
      CALL STEP
      IF((IFLAG.NE.0) .AND.((K-1).LE.KMX2).AND.(IPART.NE.0)) CALL PART
      IF (KALARM) 885,885,877
  877 KALARM=0
      IF (ICOUNT-25)250,9910,9910
  885 IF (NUCASE) 9960,886,9960
  886 IF (MOVE) 1800,890,1000
  890 IF (INUGSH) 960,970,966
  960 CALL PUTOUT(3)
      JXYZ=10
      IF (IPART.NE.0) CALL PPTOUT(3)
  970 K=K+1
      IF (K-KMAX)  500,1000,1000
C     OUTER BOUNDARY CONDITIONS
 1000 KBOUND=1
      IKK=0
      SPUT=0.0
      CALL KBDRY
      IF(MOVE) 801,1025,801
 1025 MOVE=0
      IF (KALARM) 1030,1030,877
 1030 IF (NUCASE) 9960,1050,9960
 1050 Y2(K)=Y2(K-1)+DELY(K)
      IF (INUGSH) 1060,1070,1060
 1060 CALL PUTOUT(3)
      JXYZ=11
      IF (IPART.NE.0) CALL PPTOUT(3)
 1070 IF (IFLAG) 1080,1150,1080
 1080 MAX=KMPLX+1
      DO 1100 L=2,MAX
      J=L-1
      R(J)=R2(J)
      X(J)=X2(J)
      XMI(J)=XMI2(J)
      IF (J-1) 1100,1100,1062
 1062 U(J)=U2(J)
      P(J)=P2(J)
      T(J)=T2(J)
      RHO(J)=RHO2(J)
      ZMA=1.0
      DO 1088 I=1,NDS
 1088 ZMA=ZMA+C(2,I,J)/MW(I)

      ZMA=1.0/ZMA
      ZMA(J)=ZMA
      DO 1088 I=1,NDS
      C(I,J)=C2(I,J)
 1088 XS(I,J)=C(I,J)*ZMA/MW(I)
      H(J)=0.0
      DO 1088 I=1,NDS
      DO 1088 JJ=1,NN
 1088 H(J)=H(J)+A(I,JJ)*T(J)**(JJ-2)*C(I,J)
      Y(J)= Y(J-1)+DELY(J)
      SX(J)=SX(J)+DELS(J)
 1100 CONTINUE
      IF (IKIND.GT.3) CALL SHOCKE
      ICONT=ICONT+1
      IF ((IFLAG.NE.0).AND.(IPART.NE.0))CALL PBNDY
      KMAX2= KMAX2
      LL=LL+1
      ICOUNT=0
      IF(MOD(ICONT,INTGER)) 201,1130,201
  201 IF(X (2).LT.XLMAX) GO TO 200
      XLSP=XLSP+XLASS
 1130 KMAX=1
      CALL PUT (1(1))
      IF ((IFLAG.NE.0).AND.(IPART.NE.0))CALL PPTOUT(1)
      GO TO 200
 1150 IF (IKIND.GE.4) CALL SHOCKE
      IFLAG=1
      GO TO 5
C     ERROR MESSAGES
 9910 NUCASE=78
 9955 IERROR=1
 9960 IF (IERROR.EQ.0) GO TO 9964
      WRITE (6,9985) ERROR(IERROR),NUCASE
      WRITE (6,9980) IFLAG,ICONT,ICOUNT,MOVE,KALARM,IXYZ,JXYZ
C     CALL PCLMP (A(1,1),N,5)
      DO 9969 I=1,NDS
      IF(C2(I,K).LT.0.0) GO TO 9961
 9969 CONTINUE
      GO TO 9988
 9964 WRITE(6,9983) IERROR
      WRITE (6,9980) IFLAG,ICONT,ICOUNT,MOVE,KALARM,IXYZ,JXYZ
 9980 FORMAT (1H0,10X,23HPROGRAM EXIT CONDITIONS,/15X,6HIFLAG=,I3,4X,
     1 6HICONT=,I3,4X,7HICOUNT=,I3,4X,5HMOVE=,I3,4X,7HKALARM=,I3,
     2  /15X,14HSUBROUTINE NO.,I3,5X,8HAREA NO.,I3/)
 9985 FORMAT (1H0,/10X,7HERROR =,I3/)
      GO TO 9988
 9961 WRITE(6,9962)
 9962 FORMAT(2X,11HNEGATIVE C2)
 9983 FORMAT(27HIERROR ORIGIN IN SUBROUTINE,1X,A6,19H,  STATEMENT NUMBER
     A,I6,1H.)
 9988 CONTINUE
      CALL EXIT
      END
```

```
      SUBROUTINE BNDRY                                                  BNDRY   2
C     THIS SUBROUTINE HANDLES MOST BOUNDARY CONDITIONS                  BNDRY   3
      COMMON A(25,7)      ,AA(40)      ,ALFA(25,25),ALPHAH   ,ALPHAP    A       2
     1       ,ATOL       ,BETAP      ,BMIX       ,C11(25)   ,C(25,40)   A       3
     2       ,C12(25)    ,C2(25,40)  ,CABAR(25)  ,CBBAR(25) ,CP         A       4
     3       ,CPS(25)    ,CPSH       ,CSH(25)    ,CSH1(25)  ,CSTREM(25) A       5
     4       ,HXSTRM     ,D2IN(25,25),DEFF(25)   ,D2EFF(25) ,DELTA      A       6
     5       ,D11        ,DELSS(40)  ,DELS       ,DELSO     ,DLS(40)    A       7
     6       ,DIM(25,25) ,D12        ,DELY(40)   ,D13       ,DPDY(40)   A       8
     7       ,D14        ,DPHIDS(40) ,EPCON                             A       9
     8       ,EPSLON     ,EXTRA(50)  ,FSTEP      ,FMAX      ,GRAD       A      10
     9       ,H11        ,H(40)      ,HH         ,HJ        ,HPM(25)    A      11
     *       ,H2PM(25)   ,H3PM(25)   ,ICONST     ,ICOUNT    ,IDENT(25)  A      12
     1       ,IERROR     ,IEXTRA(50) ,IFLAG      ,IKIND                 A      13
     2       ,IPTOC      ,ISHOCK     ,ITYPE      ,IPO                   A      14
     3       ,IDIFF      ,K          ,KAY        ,KAYS      ,KAY2       A      15
     4       ,KEQ        ,KMAX                                          A      16
     5       ,KUP        ,KK         ,LL         ,LPLANE    ,MA         A      17
     6       ,MASH       ,MDOT       ,MMAX       ,MU0       ,MU         A      18
     7       ,MU2        ,MUS        ,MM         ,MM2       ,MMSH       A      19
     8       ,NBOUND     ,NDS        ,NITER      ,NMAX      ,NN         A      20
      COMMON NUCASE      ,OMEGA(25)  ,P11        ,P(40)     ,P12        A      21
     1       ,P2(40)                 ,PB(50)     ,PABAR     ,PBBAR      A      22
     2       ,PBS        ,P15        ,PHI(40)               ,PHIN(50)   A      23
     3       ,PHISH1     ,PHSTRM                ,PHIW(50)  ,P18        A      24
     4       ,PHI2(40)   ,PHIBS      ,PI         ,PH(25)    ,PSH        A      25
     5       ,PSH1       ,PSI        ,PSTREM                ,PW(50)     A      26
     6       ,Q11        ,Q(40)      ,QXTR1      ,QXTR2                 A      27
     7       ,QW(50)     ,R11        ,R(40)                 ,RB(50)     A      28
     8       ,RBS        ,R13        ,RBAR(40)   ,R14       ,R2(40)     A      29
     9       ,RCON       ,R15        ,RE(40)     ,RESH      ,R16        A      30
     *       ,RHO(40)    ,R17        ,RHO2(40)   ,RHS(25)   ,RHSEN      A      31
     1       ,RHSMON     ,RHABAR     ,RHBBAR     ,RO        ,RSH        A      32
     2       ,RSTREM     ,RV         ,R19        ,RW(100)   ,S          A      33
     3                   ,SB(50)     ,SC(25)                ,SA(50)     A      34
     4       ,S13        ,SX(40)     ,T11        ,T(40)     ,T12        A      35
     5       ,T2(40)     ,TABAR      ,TBBAR      ,TO(25)    ,T14        A      36
     6       ,TAA(40)    ,TXTR1      ,TXTR2      ,TOL       ,TSH        A      37
     7       ,TSH1       ,TSTREM                 ,TW(50)    ,TWS        A      38
     8       ,TS         ,U11        ,U(40)      ,U12       ,U2(40)     A      39
      COMMON UXTR1       ,UXTR2      ,U14        ,UBAR(40)  ,USH        A      40
     1       ,USH1       ,USTREM                 ,UW(50)    ,UWS        A      41
     2       ,X11        ,X(40)      ,X12        ,X2(40)                A      42
     3       ,XB(50)     ,XBS        ,XABAR(25)  ,XBBAR(25) ,X15        A      43
     4       ,XS(25,40)  ,XSH        ,XSTREM                ,XW(50)     A      44
     5       ,ZMKK(40)               ,Y11        ,Y(40)     ,Y12        A      45
     6       ,Y2(40)     ,YABAR      ,YBBAR      ,ZA(25)    ,Z11(25)    A      46
     7       ,ZJ(25,40)  ,ZWW        ,S2X        ,R2SH      ,X2SH       A      47
     8       ,FX(2,40)   ,FR(2,40)   ,FPHI(2,40) ,FP(2,40)  ,FT(2,40)   A      48
     9       ,FU(2,40)   ,INDL(2,40) ,INDH(2,40) ,FL(2,40,25),CARD1     A      49
     *       ,M          ,N                                             A      50
      REAL    KAY         ,KAYS(25)   ,KAY2       ,KK        ,MDOT(40)  BNDRY   5
     *       ,MA(40)     ,MU         ,MUS(25)    ,MU0(25)   ,MU2        BNDRY   6
     *       ,MW(25)     ,MX2        ,MASH       ,MASH1     ,MASH       BNDRY   7
     * ,      MAP                                                       BNDRY   8
      COMMON/IDUGS1/ IMUGSH                                             BNDRY   9
      COMMON/XYZ/IXYZ,JXYZ                                              BNDRY  10


      EQUIVALENCE (MOVE,IEXTRA(15))                                     BNDRY  11
      EQUIVALENCE (MASH,EXTRA(11))                                      BNDRY  12
      IXYZ=2                                                            BNDRY  13
      JXYZ=0                                                            BNDRY  14
      IF (MOVE) 4950,50,4950                                            BNDRY  15
   50 IF (NBOUND) 3100,100,3100                                         BNDRY  16
C     WALL CONDITIONS                                                   BNDRY  17
  100 K=1                                                               BNDRY  18
      IF (ITYPE-2) 200,110,101                                          BNDRY  19
  110 PWSH=PW(1)+(PW(2)-PW(1))*S/SW(2)                                  BNDRY  20
      GO TO 101                                                         BNDRY  21
C     SHOCK BOUNDARY                                                    BNDRY  22
  101 IF (IFLAG) 103,102,103                                            BNDRY  23
  102 DPDY(K)=2.0*(P(K+1)-PWSH)/(Y(K+1)-Y(K))                           BNDRY  24
      DPHIDS(K)=-DPDY(K)*BETAP/(RHO(K+1)*U(K+1)**2)                     BNDRY  25
      GO TO 104                                                         BNDRY  26
  103 DPDY(K)=2.0*(P2(K+1)-PWSH)/(Y2(K+1)-Y(K))                         BNDRY  27
      DPHIDS    =-DPDY(K)*BETAP/(RHO2(K+1)*U2(K+1)**2)                  BNDRY  28
      DPHIDS(K)=.45*DPHIDS(K)+.55*DPHIDS                                BNDRY  29
  104 PHI2(K)=PHI(K)+DPHIDS(K)*DLS(K)                                   BNDRY  30
      IF (ABS(PHI2(K)-PHI(K))-10.0**(-4)) 105,105,106                   BNDRY  31
  105 X2(K)=X(K)+DLS(K)*COS(PHI(K))                                     BNDRY  32
      R2(K)=R(K)+DLS(K)*SIN(PHI(K))                                     BNDRY  33
      GO TO 107                                                         BNDRY  34
  106 RADR=DLS(K)/(PHI(K)-PHI2(K))                                      BNDRY  35
      X0=X(K)+RADR*SIN(PHI(K))                                          BNDRY  36
      R0=R(K)-RADR*COS(PHI(K))                                          BNDRY  37
      X2(K)=X0-RADR*SIN(PHI2(K))                                        BNDRY  38
      R2(K)=R0+RADR*COS(PHI2(K))                                        BNDRY  39
  107 Y2(K)=0.0                                                         BNDRY  40
      Y(K)=0.0                                                          BNDRY  41
      MAX=KMAX                                                          BNDRY  42
      IF (ITYPE-3) 575,1075,1075                                        BNDRY  43
 1075 CALL SHOCAL                                                       BNDRY  44
      IF (KMAX-MAX) 108,108,109                                         BNDRY  45
  108 K=1                                                               BNDRY  46
      GO TO 575                                                         BNDRY  47
  109 K=2                                                               BNDRY  48
      GO TO 575                                                         BNDRY  49
  200 K=1                                                               BNDRY  50
      MAX=KMAX                                                          BNDRY  51
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C     FIXED WALL                                                        BNDRY  52
  300 IF (S-SW(M+1)) 500,500,400                                        BNDRY  53
  400 M=M+1                                                             BNDRY  54
      IF (M-MMAX) 300,300,9030                                          BNDRY  55
  500 K=1                                                               BNDRY  56
      Y(K)=0.0                                                          BNDRY  57
      Y2(K)=0.0                                                         BNDRY  58
      PHI2(K)=PHIW(M)+(PHIW(M+1)-PHIW(M))*(S-SW(M))/(SW(M+1)-SW(M))    BNDRY  59
      IF (ABS(PHIW(M+1)-PHIW(M))-10.**(-4)) 525,525,550                 BNDRY  60
  525 X2(K)=XW(M)+(XW(M+1)-XW(M))*(S-SW(M))/(SW(M+1)-SW(M))            BNDRY  61
      R2(K)=RW(M)+(RW(M+1)-RW(M))*(S-SW(M))/(SW(M+1)-SW(M))            BNDRY  62
      GO TO 575                                                         BNDRY  63
  550 RADW=DELSO/(PHI(K)-PHI2(K))                                       BNDRY  64
      XO=X(K)+RADW*SIN(PHI(K))                                          BNDRY  65
      RO=R(K)-RADW*COS(PHI(K))                                          BNDRY  66
      X2(K)=XO-RADW*SIN(PHI2(K))                                        BNDRY  67


      R2(K)=RADW*COS(PHI2(K))+RO                                        BNDRY  68
  575 IF (IFLAG) 600,900,600                                            BNDRY  69
  600 RBAR(K)=.5*(R(K)+R2(K))                                           BNDRY  70
      RBAR(K+1)=.5*(R(K+1)+R2(K+1))                                     BNDRY  71
      YABAR=.5*(Y(K+1)+Y2(K+1))                                         BNDRY  72
      YBBAR=0.0                                                         BNDRY  73
      UBAR(K+1)=SQRT(.5*(U(K+1)**2+U2(K+1)**2))                         BNDRY  74
      RHABAR=.5*(RHO(K+1)+RHO2(K+1))                                    BNDRY  75
      TABAR=.5*(T(K+1)+T2(K+1))                                         BNDRY  76
      PABAR=.5*(P(K+1)+P2(K+1))                                         BNDRY  77
      MW2=0.0                                                           BNDRY  78
      DO 700 I=1,NOS                                                    BNDRY  79
      CABAR(I)=.5*(C(I,K+1)+C2(I,K+1))                                  BNDRY  80
  700 MW2=MW2+CABAR(I)/MW(I)                                            BNDRY  81
      MW2=1.0/MW2                                                       BNDRY  82
      DO 800 I=1,NOS                                                    BNDRY  83
      XABAR(I)=CABAR(I)*MW2/MW(I)                                       BNDRY  84
      H2PP(I)=0.0                                                       BNDRY  85
      HPM(I)=0.0                                                        BNDRY  86
      DO 800 J=1,NN                                                     BNDRY  87
  800 HPM(I)=HPM(I)+A(I,J)*TABAR**(J-2)                                 BNDRY  88
      GO TO 1050                                                        BNDRY  89
  900 RBAR(K)=R(K)                                                      BNDRY  90
      RBAR(K+1)=R(K+1)                                                  BNDRY  91
      YABAR=Y(K+1)                                                      BNDRY  92
      YBBAR=0.0                                                         BNDRY  93
      UBAR(K+1)=U(K+1)                                                  BNDRY  94
      RHABAR=RHO(K+1)                                                   BNDRY  95
      TABAR=T(K+1)                                                      BNDRY  96
      PABAR=P(K+1)                                                      BNDRY  97
      DO 1000 I=1,NOS                                                   BNDRY  98
      CABAR(I)=C(I,K+1)                                                 BNDRY  99
      XABAR(I)=XS(I,K+1)                                                BNDRY 100
      H2PP(I)=0.0                                                       BNDRY 101
      HPM(I)=0.0                                                        BNDRY 102
      DO 1000 J=1,NN                                                    BNDRY 103
 1000 HPM(I)=HPM(I)+A(I,J)*T(K+1)**(J-2)                                BNDRY 104
 1050 IF (IEXTRA(1)) 1100,1200,1100                                     BNDRY 105
 1100 MULT=0                                                            BNDRY 106
      IBIG=1                                                            BNDRY 107
      KK=K+1                                                            BNDRY 108
      CALL TRANSP (TABAR,PABAR,KK,MULT,IBIG)                            BNDRY 109
 1200 TAW(K)=0.0                                                        BNDRY 110
      G(K)=0.0                                                          BNDRY 111
      DO 1300 I=1,NOS                                                   BNDRY 112
 1300 ZJ(I,K)=0.0                                                       BNDRY 113
 1500 IF (KMAX-KAX) 1510,1510,1520                                      BNDRY 114
 1510 K=2                                                               BNDRY 115
      GO TO 10000                                                       BNDRY 116
 1520 K=3                                                               BNDRY 117
      GO TO 10000                                                       BNDRY 118
C     OUTER BOUNDARY CONDITIONS                                         BNDRY 119
 3100 K=1                                                               BNDRY 120
      IF (LL) 3110,3110,3190                                            BNDRY 121
 3110 D=SQRT((X(K)-XB(N))**2+(R(K)-RB(N))**2)                           BNDRY 122
      IF (ABS(PHI(K)-PHIB(N))-1.E-04) 3120,3120,3130                    BNDRY 123
 3120 SX(K)=D                                                           BNDRY 124


      GO TO 3190                                                        BNDRY 125
 3130 SX(K)=D*(PHI(K)-PHIB(N))/(2.*SIN(0.5*(PHI(K)-PHIB(N))))           BNDRY 126
 3190 GO TO (3200,5000,5100,5700), IKIND                                BNDRY 127
C     FIXED BOUNDARY                                                    BNDRY 128
 3200 K=1                                                               BNDRY 129
      SSX=SX(K)+DLS(K-1)                                                BNDRY 130
 3300 IF (SSX-SB(N+1)) 3500,3500,3400                                   BNDRY 131
 3400 N=N+1                                                             BNDRY 132
      IF (N-NMAX) 3300,9050,9050                                        BNDRY 133
 3500 IF (ABS(PHIB(N+1)-PHIB(N))-1.E-04) 3600,3600,3700                 BNDRY 134
 3600 PHIBAR=0.5*(PHI2(K-1)+PHIB(N))                                    BNDRY 135
      TPHBR=TAN(PHIBAR)                                                 BNDRY 136
      IF (ABS(PHIBAR)-1.E-04) 3620,3620,3640                            BNDRY 137
 3620 X2(K)=X2(K-1)                                                     BNDRY 138
      GO TO 3660                                                        BNDRY 139
 3640 X2(K)=(R2(K-1)-R(K)+TAN(PHIB(N))*X(K)+X2(K-1)/TPHBR      )/(TAN(PH BNDRY 140
     *IB(N))+1./ TPHBR)                                                 BNDRY 141
 3660 R2(K)=R(K)+TAN(PHIB(N))*(X2(K)-X(K))                              BNDRY 142
      PHI2(K)=PHIB(N)                                                   BNDRY 143
      GO TO 4200                                                        BNDRY 144
 3700 RADB=(SB(N+1)-SB(N))/(PHIB(N)-PHIB(N+1))                          BNDRY 145
      ELL1=SQRT((XB(N+1)-XB(N))**2+(RB(N+1)-RB(N))**2)                  BNDRY 146
      ELL2=SQRT(RADB**2-ELL1**2/4.)                                     BNDRY 147
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      FIOTA=ATAN((RB(K+1)-RB(K))/(XB(K+1)-XB(K)))                        BNDRY    148
      IF (RADB) 3740,3740,3720                                           BNDRY    149
 3720 XX=XB(K)+.5*(XB(K+1)-XB(K))+ELL2*SIN(FIOTA)                        BNDRY    150
      RR=RB(K)+.5*(RB(K+1)-RB(K))-ELL2*COS(FIOTA)                        BNDRY    151
      GO TO 3800                                                         BNDRY    152
 3740 XX=XB(K)+.5*(XB(K+1)-XB(K))-ELL2*SIN(FIOTA)                        BNDRY    153
      RR=RB(K)+.5*(RB(K+1)-RB(K))+ELL2*COS(FIOTA)                        BNDRY    154
 3800 L=1                                                                BNDRY    155
      EXS=X(K)+DLS(K-1)*COS(PHI(K))                                      BNDRY    156
      IF (RADB) 3820,3840,3840                                           BNDRY    157
 3820 AMR=RR-SQRT(RADB**2-(EXS-XX)**2)                                   BNDRY    158
      GO TO 3900                                                         BNDRY    159
 3840 AMR=RR+SQRT(RADB**2-(EXS-XX)**2)                                   BNDRY    160
 3900 PHIBAR=.5*(PHI2(K-1)+ATAN((EXS-XX)/(RR-AMR)))                      BNDRY    161
      TPHBR=TAN(PHIBAR)                                                  BNDRY    162
      GEE=(R2(K-1)-RR-(EXS-X2(K-1))/TPHBR       )**2-RADB**2+(EXS-XX)**2 BNDRY    163
      DRDX=(EXS-XX)/SQRT(RADB**2-(EXS-XX)**2)                            BNDRY    164
      IF (RADB) 3910,3910,3905                                           BNDRY    165
 3905 DRDX=-DRDX                                                         BNDRY    166
 3910 DPHDX=-.5*((AMR-RR)+(EXS-XX)*DRDX)/RADB**2                         BNDRY    167
      DTPH=DPHDX/(COS(PHIBAR))**2                                        BNDRY    168
      DGEEDX=2.*((EXS-XX)-(R2(K-1)-RR-(EXS-X2(K-1))/TPHBR       )*(1./   BNDRY    169
     1TPHBR    -(EXS-X2(K-1))*DTPH/(TAN(PHIBAR))**2))                    BNDRY    170
      DX=-GEE/DGEEDX                                                     BNDRY    171
      L=L+1                                                              BNDRY    172
      EXS=EXS+DX                                                         BNDRY    .73
      IF (RADB) 3920,3940,3940                                           BNDRY    174
 3920 AMR=RR-SQRT(RADB**2-(EXS XX)**2)                                   BNDRY    175
      GO TO 4000                                                         BNDRY    176
 3940 AMR=RR+SQRT(RADB**2-(EXS-XX)**2)                                   BNDRY    177
 4000 IF (L-4) 3900,4100 4100                                            BNDRY    178
 4100 X2(K)=EXS                                                          BNDRY    179
      R2(K)=AMR                                                          BNDRY    180
      PHI2(K)=-ATAN((EXS-XX)/(AMR-RR))                                   BNDRY    181


 4200 D=SQRT((X2(K)-X(K))**2+(R2(K)-R(K))**2)                            BNDRY    182
      IF (ABS(PHI2(K)-PHI(K))-1.E-04) 4300,4300,4400                     BNDRY    183
 4300 DLS(K)=D                                                           BNDRY    184
      GO TO 4500                                                         BNDRY    18
 4400 DLS(K)=D*(PHI2(K)-PHI(K))/(2.*SIN(0.5*(PHI2(K)-PHI(K))))           BNDRY    186
 4500 D=SQRT((X2(K)-X2(K-1))**2+(R2(K)-R2(K-1))**2)                      BNDRY    187
      IF (ABS(PHI2(K)-PHI2(K-1))-1.E-04) 4600,4600,4700                  BNDRY    188
 4600 DELY(K)=D                                                          BNDRY    189
      GO TO 4800                                                         BNDRY    190
 4700 DELY(K)=D*(PHI2(K)-PHI2(K-1))/(2.0* IN(.5*(PHI2(K)-PH , K-1))))    BNDRY    191
 4800 AA(K)=PI*(R2(K)+R2(K-1))*DELTAPDE  (K)                             BNDRY    192
      Y2(K)=Y2(K-1)+DELY(K)                                              BNDRY    193
 4900 CALL STEP                                                          BNDRY    194
      JAY=1                                                              BNDRY    195
 4950 MOVE=0                                                             BNDRY    196
      GO TO 10000                                                        BNDRY    197
C     FREE BOUNDARY                                                      BNDRY    198
 5000  =1                                                                BNDRY    199
      PHS=PB(N)+(PB(N+1)-PB(N))*(S2X-SB(N))/(SB(N+1)-SB(N))              BNDRY    200
      GO TO 5700                                                         BNDRY    201
C     FEATENIAN BOUNDARY                                                 BNDRY    202
 5100 FMSTRM=0.0                                                         BNDRY    203
      DO 5300 I=1,NOS                                                    BNDRY    204
 5300 FMSTRM=FMSTRM+CSTREM(I)/RR(I)                                      BNDRY    205
      FMSTRM=1.0/FMSTRM                                                  BNDRY    206
      GSTRM=PSTREM*FMSTRM*(USTREM**2)/(RV*TSTREM*BETAP)                  BNDRY    207
 5400 IF (IFLAG) 5525,5500,5525                                          BNDRY    208
 5500 SIGMA=PHI(K)-FMSTRM                                                BNDRY    209
      GO TO 5550                                                         BNDRY    210
 5525 SIGMA=.5*(PHI(K)+PHI2(K))-FMSTRM                                   BNDRY    211
 5550 IF (SIGMA) 5575,5575,5600                                          BNDRY    212
 5575 PBS=PSTREM                                                         BNDRY    213
      GO TO 5700                                                         BNDRY    214
 5600 IF (SIGMA-0.5*PI) 5650,5650,5625                                   BNDRY    215
 5625 PHS=PSTREM+GSTRM                                                   BNDRY    216
      GO TO 5700                                                         BNDRY    217
 5650 PBS=PSTREM+GSTRM *(SIN(SIGMA))**2                                  BNDRY    218
      IF (TROUGH.NE.0) WRITE(6,9901) K,IFLAG,Y(K),Y(K-1),RHO(K),U(K),    BNDRY    219
     1 Y2(K),Y2(K-1),RHO2(K),U2(K)  ,SIGMA,PHS                           BNDRY    220
 9901 FORMAT(1X,2I5,10F11.3)                                             BNDRY    221
 5700 IF (IFLAG) 5900,5800,5900                                          BNDRY    222
 5800 CPDY(K)=2.0*(PHS-P(K))/(Y(K)-Y(K-1))                               BNDRY    223
      CPHIDS(K)=-CPDY(K)*BETAP/(RHO(K)*U(K)**2)                          BNDRY    224
      GO TO 6000                                                         BNDRY    225
 5900 CPDY(K)=2.0*(PHS-P2(K))/(Y2(K)-Y2(K-1))                            BNDRY    226
      CPHDS=-DPDY(K)*BETAP/(RHO2(K)*U2(K)**2)                            BNDRY    227
      DPHIDS(K)=.45*DPHIDS(K)+.55*DPHDS                                  BNDRY    228
 6000 MOVE=1                                                             BNDRY    229
      RETURN                                                             BNDRY    230
C     ERROR MESSAGES                                                     BNDRY    231
 9000 NOCASE=100                                                         BNDRY    232
      GO TO 9900                                                         BNDRY    233
 9050 NOCASE=400                                                         BNDRY    234
      GO TO 9900                                                         BNDRY    235
 9050 NOCASE=5200                                                        BNDRY    236
 9900 IERROR=2                                                           BNDRY    237
10000 RETURN                                                             BNDRY    238


      END                                                                BNDRY    239
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      SUBROUTINE CHEM(IKINE)                                                  CHEM
      COMMON A(25,7)     ,AA(40)       ,ALFA(25,25),ALPHAM    ,ALPHAP         A
     1       ,ATOL       ,BETAP        ,BMIX         ,C11(25)     ,C(25,40)     A
     2       ,C12(25)    ,C2(25,40)    ,CABAR(25)    ,CBBAR(25)   ,CP           A
     3       ,CPS(25)    ,CPSH         ,CSH(25)      ,CSH1(25)    ,CSTREM(25)   A
     4       ,MXSTRM     ,D21M(25,25),DEFF(25)       ,D21FF(25)   ,DELTA        A
     5       ,D11        ,DELBB(40)    ,DELB         ,DELBO       ,DLB(40)      A
     6       ,DIM(25,25) ,D12          ,DELY(40)     ,D13         ,DPBY(40)     A
     7       ,D14        ,DPHIDS(40)   ,EPCON                                   A
     8       ,EPSLON     ,EXTRA(50)    ,FSTEP        ,FMAX        ,GRAD         A
     9       ,H11        ,H(40)        ,HH           ,HJ          ,HPM(25)      A
     *       ,H2PM(25)   ,H3PM(25)     ,ICONST       ,ICOUNT      ,IDENT(25)    A
     1       ,IERROR     ,IEXTRA(50)   ,IFLAG        ,IKIND                     A
     2       ,IPTOC      ,ISHOCK       ,ITYPE        ,IPD                       A
     3       ,IDIFF      ,K            ,KAY          ,KAYS        ,KAY2         A
     4       ,KLO        ,KMAX                                                  A
     5       ,KUP        ,KK           ,L            ,LPLANE      ,MA           A
     6       ,MASH       ,MOUT         ,MMAX         ,MUO         ,MU           A
     7       ,MU2        ,MUS          ,MM           ,MM2         ,MMSH         A
     8       ,NBOUND     ,NDS          ,NITER        ,NMAX        ,NN           A
      COMMON NUCASE      ,OMEGA(25)    ,P11          ,P(40)       ,P12          A
     1       ,P2(40)                   ,PB(50)       ,PABAR       ,PUBAR        A
     2       ,PHS        ,P15          ,PHI(40)                   ,PHIB(50)     A
     3       ,PHISH1     ,PHSTRM                     ,PHIM(50)    ,P16          A
     4       ,PHI2(40)   ,PHIBS        ,P1           ,PK(25)      ,PSH          A
     5       ,PSH1       ,PSI          ,PSTREM                    ,PN(50)       A
     6       ,Q11        ,Q(40)        ,QXTR1        ,QXTR2                     A
     7       ,QN(50)     ,R11          ,R(40)                     ,RB(50)       A
     8       ,RHS        ,R15          ,RBAR(40)     ,R14         ,R2(40)       A
     9       ,RCON       ,R15          ,RE(40)       ,RESH        ,R16          A
     *       ,RHO(40)    ,R17          ,RHO2(40)     ,RHB(25)     ,RHREM        A
     1       ,RHSHM      ,RHABAR       ,RHBBAR       ,RU          ,R M          A
     2       ,RSTREM     ,RV           ,R19          ,RN(100)     ,S            A
     3                   ,SB(50)       ,SC(25)                    ,SN(50)       A
     4       ,S13        ,SX(40)       ,T11          ,T(40)       ,T12          A
     5       ,T2(40)     ,TABAR        ,TBBAR        ,T0(25)      ,T14          A
     6       ,TAN(40)    ,TXTR1        ,TXTR2        ,TOL         ,TSH          A
     7       ,TSH1       ,TSTREM                     ,TN(50)      ,TNS          A
     8       ,TS         ,U11          ,U(40)        ,U12         ,U2(40)       A
      COMMON UXTR1       ,UXTR2        ,U14          ,UBAR(40)    ,USH          A
     1       ,USH1       ,USTREM                     ,UN(50)      ,UNS          A
     2       ,X11        ,X(40)        ,X12          ,X2(40)                    A
     3       ,XN(50)     ,XNB          ,XABAR(25)    ,XBBAR(25)   ,X15          A
     4       ,XS(25,40)  ,XSH          ,XSTREM                    ,XN(50)       A
     5       ,ZMAK(40)                 ,Y11          ,Y(40)       ,Y12          A
     6       ,Y2(40)     ,YABAR        ,YBBAR        ,ZA(25)      ,Z11(25)      A
     7       ,ZJ(25,40)  ,ZPA          ,S2X          ,X2SH        ,X2SH         A
     8       ,FX(2,40)   ,FR(2,40)     ,FPH1(2,40) ,FP(2,40)      ,F1(2,40)     A
     9       ,FU(2,40)   ,INDL(2,40)   ,INDR(2,40)   ,FC(2,40,25),CARD1         A
     *       ,M          ,N                                                     A
      REAL    KAY        ,KAYS(25)     ,KAY2         ,KN          ,MDOT(40)     CHEM
     *       ,MA(40)     ,MU           ,MUS(25)      ,MUO(25)     ,MU2          CHEM
     *       ,MW(25)     ,MW2          ,MASH         ,MASH1       ,MWSH         CHEM
     *  ,      MAP                                                              CHEM
      DIMENSION G(25),HP(25),HM(25)                                             CHEM
      COMMON/CHEM1/ Z10(5), IRR(40),IR1(40),RC(40,3),IRRR(40,5),                CHEM
     1 AV,CM(26,26),F1(26),WP(26),                                              CHEM

     2 AP(26),FOUT(26,40),CSI(26),GX(26)                                        CHEM
      COMMON/IHUGS1/ IHUGSH                                                     CHEM
      COMMON/XYZ/IXYZ,JXYZ                                                      CHEM
C     GAS CONSTANT IN 1.987 CAL/G-MOLE-K                                        CHEM
      IXYZ=3                                                                    CHEM
      JXYZ=0                                                                    CHEM
      RR=1.987*T(K)                                                             CHEM
C     GAS CONSTANT IN 82.06 CM3-ATM/G-MOLE-K                                    CHEM
      RRT=82.06*T(K)                                                            CHEM
      XLOGT=ALOG(T(K))                                                          CHEM
      XLLGT=ALOG(T(K)/1000.0)                                                   CHEM
      DO 3 IR=1,NDS                                                             CHEM
      F1(IR)=C(IR,K)/MW(IR)                                                     CHEM
      GX(IR)=0.0                                                                CHEM
      WP(IR)=0.0                                                                CHEM
      WM(IR)=0.0                                                                CHEM
      WDOT(IR,K)=0.0                                                            CHEM
      DO 4 JR=1,NDS                                                             CHEM
    4 CM(IR,JR)=0.0                                                             CHEM
    3 CONTINUE                                                                  CHEM
C       CALCULATING GIBBS ENERGY                                                CHEM
      DO 6 IR=1,NDS                                                             CHEM
      G(IR)=A(IR,1)*.5/T(K)+(A(IR,3)*(1.-XLLGT) -CSI(IR))*T(K)+A(IR,2)          CHEM
      IF (KK.LT.4) GO TO 7                                                      CHEM
      G(IR)=G(IR)-A(IR,4)*T(K)**2*.5*A(IR,5)*T(K)**3-A(IR,6)/3.*T(K)***         CHEM
    7 G(IR)= G(IR)*RR(IR)                                                       CHEM
C   CALCULATE GIBBS ENERGY IN CAL/MOLE                                          CHEM
    6 CONTINUE                                                                  CHEM
      DO 1 IR=1,IRINE                                                           CHEM
      KINT=IRT(IR)                                                              CHEM
      GO TO (841,842,843,844,845,846,847,848),KINT                              CHEM
  848 RKF=RC(IR,1)*(T(K)**RC(IR,2))*EXP(RC(IR,3)/RRT)                           CHEM
      GO TO 849                                                                 CHEM
  841 RKF=RC(IR,1)                                                              CHEM
      GO TO 849                                                                 CHEM
  842 RKF=RC(IR,1)/T(K)                                                         CHEM
      GO TO 849                                                                 CHEM
  843 RKF=RC(IR,1)/T(K)/T(K)                                                    CHEM
      GO TO 849                                                                 CHEM
  844 RKF=RC(IR,1)/SQRT(T(K))                                                   CHEM
      GO TO 849                                                                 CHEM
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```
845 RRF=RC(IR,1)*EXP(RC(IR,3)/RRT)
    GO TO 849
846 RRF=RC(IR,1)*EXP(RC(IR,3)/RRT)/T(K)
    GO TO 849
847 RRF=RC(IR,1)/T(K)/SQRT(T(K))
849 CONTINUE
    KIRR=IRR(IR)
    GO TO (851,852,853,854,855,856,857,858,859,860),KIRR
851 J1=IRRR(IR,1)
    J2=IRRR(IR,2)
    J3=IRRR(IR,3)
    J4=IRRR(IR,4)
    E=(G(J1)+G(J2)-G(J3)-G(J4))/RRT
    IF (E.LT.-40.0) E=-40.0
    IF (E .GT. +40.0) E=+40.0
    E=EXP(E)


    CRR=RRF*RHO(K)
    RP(IR)=CRR*FI(J1)*FI(J2)
    RM(IR)=CRR*FI(J3)*FI(J4)/E
    DO 773 J=1,4
    SIGN=1.0
    IF (J .GT. 2) SIGN=-1.0
    IRON=IRRR(IR,J)
    CM(IRON,J1)=CM(IRON,J1)+SIGN*CRR*FI(J2)
    CM(IRON,J2)=CM(IRL    2)+SIGN*CRR*FI(J1)
    CM(IRON,J3)=CM(IRON,J3)-SIGN*CRR*FI(J4)/E
    CM(IRON,J4)=CM(IRON,J4)-SIGN*CRR*FI(J3)/E
    QX(IRON)=QX(IRON)+SIGN*(RP(IR)-RM(IR))
773 CONTINUE
    GO TO 867
852 J1=IRRR(IR,1)
    J2=IRRR(IR,2)
    J3=IRRR(IR,3)
    E=(G(J1)+G(J2)-G(J3))/RRT
    IF (E .LT. -40.0) E=-40.0
    IF (E .GT. +40.0) E=+40.0
    E=EXP(E)
    CRR=RRF*RHO(K)/ZWM*AV
    RP(IR)=CRR*RHO(K)*FI(J1)*FI(J2)
    RM(IR)=CRR*FI(J3)/(E*RRT1)
    DO  774 J=1,3
    SIGN=1.0
    IF (J .GT. 2) SIGN =-1.0
    IRON=IRRR(IR,J)
    CM(IRON,J1)=CM(IRON,J1)+SIGN*CRR*RHO(K)*FI(J2)
    CM(IRON,J2)=CM(IRON,J2)+SIGN*CRR*RHO(K)*FI(J1)
    CM(IRON,J3)=CM(IRON,J3)-SIGN*CRR/(E*RRT1)
    QX(IRON)= QX(IRON)+SIGN*RP(IR)
774 CONTINUE
    GO TO 866
853 J1=IRRR(IR,1)
    J2=IRRR(IR,2)
    J3=IRRR(IR,3)
    J4=IRRR(IR,4)
    J5=IRRR(IR,5)
    E=(G(J1)+G(J2)-G(J3)-G(J4)-G(J5))/RRT
    IF (E .LT. - 40.0) E=-40.0
    IF (E .GT. +40.0) E=+40.0
    E=EXP (E)
    CRR=RRF*RHO(K)
    RP(IR)=CRR*FI(J1)*FI(J2)
    RM(IR)=CRR*FI(J3)*FI(J4)*FI(J5)*RHO(K)*RRT1/E
    DO 775 J=1,5
    SIGN = 1.0
    IF (J .GT. 2) SIGN =-1.0
    IRON=IRRR(IR,J)
    CM(IRON,J1)=CM(IRON,J1)+SIGN*CRR*FI(J2)
    CM(IRON,J2)=CM(IRON,J2)+SIGN*CRR*FI(J1)
    CM(IRON,J3)=CM(IRON,J3)-SIGN*CRR*FI(J4)*FI(J5)*RHO(K)*RRT1/E
    CM(IRON,J4)=CM(IRON,J4)-SIGN*CRR*FI(J3)*FI(J5)*RHO(K)*RRT1/E
    CM(IRON,J5)=CM(IRON,J5)-SIGN*CRR*FI(J3)*FI(J4)*RHO(K)*RRT1/E
    QX(IRON)=QX(IRON)+SIGN*(RP(IR)-2.0*RM(IR))
775 CONTINUE


    GO TO 861
854 J1=IRRR(IR,1)
    J2=IRRR(IR,2)
    J3=IRRR(IR,3)
    E=(G(J1)+G(J2)-G(J3))/RRT
    IF (E .LT. -40.0) E=-40.0
    IF (E .GT. +40.0) E=+40.0
    E=EXP(E)
    CRR=RRF*RHO(K)
    RP(IR)=CRR*FI(J1)*FI(J2)
    RM(IR)=CRR*FI(J3)/E/RRT1*RHO(K)
    DO 771 J=1,3
    SIGN=1.0
    IF (J .GT. 2) SIGN = -1.0
    IRON = IRRR(IR,J)
    CM(IRON,J1)=CM(IRON,J1)+SIGN*CRR*RHO(K)*FI(J2)
    CM(IRON,J2)=CM(IRON,J2)+SIGN*CRR*RHO(K)*FI(J1)
    CM(IRON,J3)=CM(IRON,J3)-SIGN*CRR/(E*RRT1  )*RHO(K)
    QX(IRON)=QX(IRON)+SIGN*RP(IR)
771 CONTINUE
    GO TO 868
855 J1=IRRR(IR,1)
```

```
      J2=NLS+1
      J3=IRRR(IR,3)
      J4=IRRR(IR,4)
      E=(G(J1)-G(J3)-G(J4))/RRT
      IF (E .LT. -40.0) E= -40.0
      IF (E .GT. +40.0) E=+40.0
      E=EXP (E)
      CRR=RF*RHO(K)/2**
      RP(IR)=CRR*FI(J1)
      RM(IR)=CRR*RRT1*RHO(K)*FI(J3)*FI(J4)/E
      DO 772 J=1,4
      IF (J .EQ. 2) GO TO 772
      SIGN =1.0
      IF (J .GT. 2) SIGN=-1.0
      IROW=IRRR(IR,J)
      CM(IROW,J1)=CM(IROW,J1)+SIGN*CRR
      CM(IROW,J3)=CM(IROW,J3)-SIGN*CRR*RRT1*RHO(K)*FI(J4)/E
      CM(IROW,J4)=CM(IROW,J4)-SIGN*CRR*RRT1*RHO(K)*FI(J3)/E
      QX(IROW)=QX(IROW)-SIGN*RM(IR)
  772 CONTINUE
      GO TO 867
  856 J1=IRRR(IR,1)
      J2=IRRR(IR,2)
      J3=IRRR(IR,3)
      J4=IRRR(IR,4)
      CRR=RF*RHO(K)
      RP(IR)=CRR*FI(J1)*FI(J2)
      RM(IR)=0.0
      DO 778 J=1,4
      SIGN=1.0
      IF (J .GT. 2) SIGN=-1.0
      IROW=IRRR(IR,J)
      CM(IROW,J1)=CM(IROW,J1)+SIGN*CRR*FI(J2)
      CM(IROW,J2)=CM(IROW,J2)+SIGN*CRR*FI(J1)
      QX(IROW)=QX(IROW)+SIGN*RP(IR)


  778 CONTINUE
      GO TO 867
  857 J1=IRRR(IR,1)
      J2=IRRR(IR,2)
      J3=IRRR(IR,3)
      CRR=RF*RHO(K)*AV/2**
      RP(IR)=CRR*RHO(K)*FI(J1)*FI(J2)
      RM(IR)=0.0
      DO 779 J=1,3
      SIGN=1.0
      IF (J .GT.2) SIGN=-1.0
      IROW=IRRR(IR,J)
      CM(IROW,J1)= CM(IROW,J1)+SIGN*CRR*RHO(K)*FI(J2)
      CM(IROW,J2)= CM(IROW,J2)+SIGN*CRR*RHO(K)*FI(J1)
      QX(IROW)=QX(IROW)+SIGN*RP(IR)
  779 CONTINUE
      GO TO 868
  858 J1=IRRR(IR,1)
      J2=IRRR(IR,2)
      J3=IRRR(IR,3)
      J4=IRRR(IR,4)
      J5=IRRR(IR,5)
      CRR =RF*RHO(K)
      RP(IR)=CRR *FI(J1)*FI(J2)
      RM(IR)=0.0
      DO 780 J=1,5
      SIGN=1.0
      IF (J .GT. 2) SIGN=-1.0
      IROW=IRRR(IR,J)
      CM(IROW,J1)=CM(IROW,J1)+SIGN*CRR*FI(J2)
      CM(IROW,J2)=CM(IROW,J2)+SIGN*CRR*FI(J1)
      QX(IROW)=QX(IROW)+SIGN*RP(IR)
  780 CONTINUE
      GO TO 861
  859 J1=IRRR(IR,1)
      J2=IRRR(IR,2)
      J3=IRRR(IR,3)
      CRR=RF
      RP(IR)=CRR*RHO(K)*FI(J1)*FI(J2)
      RM(IR)=0.0
      DO 776 J=1,3
      SIGN=1.0
      IF (J .GT. 2) SIGN =-1.0
      IROW = IRRR(IR,J)
      CM(IROW,J1)=CM(IROW,J1)+SIGN*CRR*RHO(K)*FI(J2)
      CM(IROW,J2)=CM(IROW,J2)+SIGN*CRR*RHO(K)*FI(J1)
      QX(IROW)=QX(IROW)+SIGN*RP(IR)
  776 CONTINUE
      GO TO 866
  860 J1=IRRR(IR,1)
      J2=NLS+1
      J3=IRRR(IR,3)
      J4=IRRR(IR,4)
      CRR=RF*RHO(K)/2**
      RP(IR)=CRR*FI(J1)
      RM(IR)=0.0
      DO 777 J=1,4


      IF (J .EQ. 2) GO TO 777
      SIGN=1.0
      IF (J .GT. 2) SIGN=-1.0
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```
      IROW = IRRR(IR,J)
      CM(IROW,J1)=CM(IROW,J1)+SIGN*CMM
  777 CONTINUE
      GO TO 867
  861 WP(J5)=WP(J5)+WP(IR)
      WM(J5)=WM(J5)+WM(IR)
  867 WP(J4)=WP(J4)+WP(IR)
      WM(J4)=WM(J4)+WM(IR)
  866 WP(J3)=WP(J3)+WP(IR)
      WM(J3)=WM(J3)+WM(IR)
      WP(J2)=WP(J2)-WP(IR)
      WM(J2)=WM(J2)-WM(IR)
      WP(J1)=WP(J1)-WP(IR)
      WM(J1)=WM(J1)-WM(IR)
    1 CONTINUE
      DO 897 J=1,NOS
C       PRODUCTION RATE IN MOLE/GM-CM
      WDOT(J,K)=(WP(J)-WM(J))/U(K)
  897 CONTINUE
      DSUM=DLS(K)/U(K)
      DO 10 IR=1,NOS
      DSWUR=DSUM*PW(IR)
      QX(IR)= C(IR,K)+WMS(IR)/WDOT(K)+DSWUR*AUX(IR)
      DO 11 JR=1,NOS
      CM(IR,JR)= CM(IR,JR)*DSWUR
      IF (IR.EQ.JR) CM(IR,JR)= 1.0+CM(IR,JR)
   11 CONTINUE
      IF (IBUGBM .NE. 0)
     *WRITE(6,100) K,IR,(CM(IR,JR),JR=1,NOS),QX(IR)
  100 FORMAT(1X,2I5,1P8E12.3)
   10 CONTINUE
      CALL SLDP(QX,CM,NOS)
      DO 12 IR=1,NOS
      IF (IBUGBM .NE. 0)
     *WRITE(6,100) K,IR,(CM(IR,JR),JR=1,NOS),QX(IR)
      C2(IR,K)= QX(IR)
C     CALCULATE NEW MASS FRACTION OF SPECIES
   12 CONTINUE
      RETURN
      END


      SUBROUTINE CPUTIN(IDENT,IKINE,NOS)
C       -----------------------------------------------------------------
      DIMENSION IDENT (25),IZO(5)
      COMMON/CHEM1/ ZI(5), IRR(40),IRT(40),RC(40,3),IRRR(40,5),
     1 AV,CM(26,26),FI(26),WP(26),
     2 WM(26),WDOT(26,40),CSI(26),QX(26)
      COMMON/XYZ/IXYZ,JXYZ
      IXYZ=4
      JXYZ=0
      AV=6.03E23
      DO 2 I=1,IKINE
      READ (5,100) (IZO(J),J=1,5),IRR(I),IRT(I),(RC(I,KK),KK=1,3)
      WRITE(6,101) I, (IZO(J),J=1,5),IRR(I),IRT(I),(RC(I,KK),KK=1,3)
      DO 5 J=1,5
      IRRR (I,J)=0
      DO 3 L=1,NOS
      IF (IZO(J)-IDENT(L)) 3,4,3
    4 IRRR(I,J)=L
    3 CONTINUE
    5 CONTINUE
      RC(I,1)=RC(I,1)*AV
    2 CONTINUE
  100 FORMAT (A4,3X,A4,10X,A4,3X,A4,3X,A4,9  I2,I1,E8.2,F4.1,F9.1)
  101 FORMAT (2X,I2,2X,A4,3X,A4,10X,A4,3X,A4,3X,A4,9X,I2,I1,E8.2,
     1 F4.1,F9.1)
      RETURN
      END


      SUBROUTINE DRAG
      COMMON A(25,7)      ,AA(40)      ,ALFA(25,2 ),ALPHAH      ,ALPHAP
     1       ,ATOL        ,BETAP       ,BMIX        ,C11(25)     ,C(25,40)
     2       ,C12(25)     ,C2(25,40)   ,CABAR(25)   ,CBBAR(25)   ,CP
     3       ,CPS(25)     ,CPSH        ,CSH(25)     ,CSH1(25)    ,CSTREM(25)
     4       ,DSSTRM      ,D2IM(25,25),DEFF(25)     ,D2EFF(25)   ,DFLTA
     5       ,D11         ,DELSS(40)   ,DELS        ,DELSO       ,DLS(40)
     6       ,DIM(25,25) ,D12         ,DFLY(40)    ,DIS         ,DPDY(40)
     7       ,D14         ,DPHIDS(10)  ,EPCON
     8       ,EPSLON      ,EXTRA(50)   ,FSTEP       ,FMAX        ,GRAD
     9       ,H11         ,H(40)       ,HH          ,HJ          ,HPM(25)
     *       ,H2PM(25)    ,H3PM(25)    ,ICONST      ,ICOUNT      ,IDENT(25)
     1       ,IERROR      ,IEXTRA(50)  ,IFLAG       ,IKIND
     2       ,IPILC       ,ISHOCK      ,ITYPE       ,IPO
     3       ,IPIFF       ,K           ,KAY         ,KAYS        ,KAY2
     4       ,KLO         ,KMAX
     5       ,KUP         ,KK          ,LL          ,LPLANE      ,MA
     6       ,MASH        ,MFLOT       ,MMAX        ,MUO         ,MU
     7       ,MU2         ,MUS         ,MW          ,MW2         ,MASH
     8       ,NBOUNL      ,NOS         ,NITER       ,NMAX        ,NN
      COMMON NUCASE      ,OMEGA(25)   ,P11         ,P(40)       ,P12
     1       ,P2(40)                   ,PB(50)      ,PABAR       ,PBBAR
     2       ,PHS         ,P15         ,PHI(40)                  ,PHIB(50)
     3       ,PHISHI      ,PFSTOM                   ,PHIW(50)    ,P18
     4       ,PHI2(40)    ,PHIBS       ,PI          ,PR(25)      ,PSH
     5       ,PSHI        ,PSI         ,PSTREM                   ,PW(50)
     6       ,Q11         ,Q(40)       ,QXTR1       ,QXTR2
     7       ,QW(50)      ,R11         ,R(40)                    ,RB(50)
```

```
      IHUN = IRRR(IR,J)
      CM(IROW,J1)=CM(IROW,J1)+SIGN*CMM
  777 CONTINUE
      GO TO 867
  861 WP(J5)=WP(J5)+WP(IR)
      WM(J5)=WM(J5)+WM(IR)
  867 WP(J4)=WP(J4)+WP(IR)
      WM(J4)=WM(J4)+WM(IR)
  866 WP(J3)=WP(J3)+WP(IR)
      WM(J3)=WM(J3)+WM(IR)
      WP(J2)=WP(J2)-WP(IR)
      WM(J2)=WM(J2)-WM(IR)
      WP(J1)=WP(J1)-WP(IR)
      WM(J1)=WM(J1)-WM(IR)
    1 CONTINUE
      DO 897 J=1,NDS
C      PRODUCTION RATE IN MOLE/GM-CM
      WDOT(J,K)=(WP(J)-WM(J))/U(K)
  897 CONTINUE
      DSUM=DLS(K)/U(K)
      DO 10 IR=1,NDS
      DSNUM=DSUM*PR(IR)
      QX(IR)= C(IR,K)+HWS(IR)/WDOT(K)+DSNUM*QX(IR)
      DO 11 JR=1,NDS
      CM(IR,JR)= CM(IR,JR)*DSNUM
      IF (IR.EQ.JR) CM(IR,JR)= 1.0+CM(IR,JR)
   11 CONTINUE
      IF (IBUGSM .NE. 0)
     *WRITE(6,100) K,IR,(CM(IR,JR),JR=1,NDS),QX(IR)
  100 FORMAT(1X,2I5,1P8E12.3)
   10 CONTINUE
      CALL SLDP(QX,CM,NDS)
      DO 12 IR=1,NDS
      IF (IBUGSM .NE. 0)
     *WRITE(6,100) K,IR,(CM(IR,JR),JR=1,NDS),QX(IR)
      C2(IR,K)= QX(IR)
C     CALCULATE NEW MASS FRACTION OF SPECIES
   12 CONTINUE
      RETURN
      END


      SUBROUTINE CPUTIN(IDENT,IKINE,NDS)
C      ************************************************************
      DIMENSION IDENT (25),IZD(5)
      COMMON/CHEM1/ ZI((5), IRR(40),IRT(40),RC(40,3),IRRR(40,5),
     1 AV,CM(26,26),FI(26),WP(26),
     2 WM(26),WDOT(26,40),CSI(26),QX(26)
      COMMON/XYZ/IXYZ,JXYZ
      IXYZ=4
      JXYZ=0
      AV=6.03E23
      DO 2 I=1,IKINE
      READ (5,100) (IZD(J),J=1,5),IRR(I),IRT(I),(RC(I,KK),KK=1,3)
      WRITE(6,101) I, (IZD(J),J=1,5),IRR(I),IRT(I),(RC(I,KK),KK=1,3)
      DO 5 J=1,5
      IRRR (I,J)=0
      DO 3 L=1,NDS
      IF (IZD(J)-IDENT(L)) 3,4,3
    4 IRRR(I,J)=L
    3 CONTINUE
    5 CONTINUE
      RC(I,1)=RC(I,1)*AV
    2 CONTINUE
  100 FORMAT (A4,3X,A4,10X,A4,3X,A4,3X,A4,9  I2,I1,E8.2,F4.1,F9.1)
  101 FORMAT (2X,I2,2X,A4,3X,A4,10X,A4,3X,A4,3X,A4,9X,I2,I1,E8.2,
     1 F4.1,F9.1)
      RETURN
      END


      SUBROUTINE DRAG
      COMMON A(25,7)      ,AA(40)      ,ALFA(25,2 ),ALPHAH     ,ALPHAP
     1        ,ATOL        ,BETAP       ,BMIX       ,C11(25)    ,C(25,40)
     2        ,C12(25)     ,C2(25,40)   ,CABAR(25)  ,CUBAR(25)  ,CP
     3        ,CPS(25)     ,CPSH        ,CSH(25)    ,CSH1(25)   ,CSTREM(25)
     4        ,MSSTRM      ,D2IH(25,25),DEFF(25)    ,D2EFF(25)  ,DELTA
     5        ,D11         ,DELSS(40)   ,DELS       ,DELSO      ,DLS(40)
     6        ,DIM(25,25)  ,D12         ,DFLY(40)   ,D1S        ,DPDY(40)
     7        ,D14         ,DPHIDS(10)  ,EPCON
     8        ,EPSLON      ,EXTRA(50)   ,FSTEP      ,FMAX       ,GRAD
     9        ,H11         ,H(40)       ,HH         ,HJ         ,HPM(25)
     *        ,H2PM(25)    ,H3PM(25)    ,ICONST     ,ICOUNT     ,IDENT(25)
     1        ,IERROR      ,IEXTRA(50)  ,IFLAG      ,IKIND
     2        ,IPTOL       ,ISHOCK      ,ITYPE      ,IPO
     3        ,IDIFF       ,K           ,KAY        ,KAYS       ,KAY2
     4        ,KLO         ,KMAX
     5        ,KOP         ,KK          ,LL         ,LPLANE     ,MA
     6        ,MASH        ,MEOT        ,MMAX       ,MUO        ,MU
     7        ,MU2         ,MOS         ,MM         ,MM2        ,MASH
     8        ,NBOUNL      ,NDS         ,NITER      ,NMAX       ,NN
      COMMON NOCASE       ,OMEGA(25)   ,P11        ,P(40)      ,P12
     1        ,P2(40)                   ,PB(50)     ,PABAR      ,PBBAR
     2        ,PHS         ,P15         ,PHI(40)                ,PHIB(50)
     3        ,PHISH1      ,PHSTOP                  ,PHIN(50)   ,PIR
     4        ,PHI2(40)    ,PHIBS       ,PI         ,PR(25)     ,PSH
     5        ,PSH1        ,PSI         ,PSTREM                 ,PW(50)
     6        ,Q11         ,Q(40)       ,QXTR1      ,QXTR2
     7        ,QW(50)      ,R11         ,R(40)                  ,RB(50)
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     8      ,RNS        ,R13         ,RBAR(40)     ,R10          ,R2(40)       A        29
     9      ,RCUM       ,R15         ,RE(40)       ,RESM         ,R16          A        30
     *      ,RHO(40)    ,R17         ,RHO2(40)     ,RHS(25)      ,RHBEN        A        31
     1      ,RHSMUM     ,RHABAR      ,RHOBAR       ,RU           ,RSM          A        32
     2      ,RSTHEM     ,RV          ,R19          ,RR(100)      ,S            A        33
     3                  ,SU(50)      ,SC(25)                     ,SM(50)       A        34
     4      ,S15        ,SX(40)      ,T11          ,T(40)        ,T12          A        35
     5      ,T2(40)     ,TABAR       ,TBBAR        ,T0(25)       ,T14          A        36
     6      ,TAP(40)    ,TXTH1       ,TXTH2        ,TOL          ,TSM          A        37
     7      ,TSM1       ,TSTHEM                    ,TM(50)       ,TAS          A        38
     8      ,TS         ,U11         ,U(40)        ,U12          ,U2(40)       A        39
      COMMON UXTH1      ,UXTH2       ,U14          ,UBAR(40)     ,USM          A        40
     1      ,USM1       ,USTHEM                    ,UM(50)       ,UMS          A        41
     2      ,X11        ,X(40)       ,X12          ,X2(40)                     A        42
     3      ,XM(50)     ,XUS         ,XABAR(25)    ,XBBAR(25)    ,X15          A        43
     4      ,XS(25,40)  ,XSM         ,XSTHEM                     ,XM(50)       A        44
     5      ,ZMMM(40)                ,Y11          ,Y(40)        ,Y12          A        45
     6      ,Y2(40)     ,YABAR       ,YBBAR        ,ZA(25)       ,Z11(25)      A        46
     7      ,ZJ(25,40)  ,ZMM         ,S2X          ,R2BM         ,X2BM         A        47
     8      ,FX(2,40)   ,FR(2,40)    ,FPH1(2,40)   ,FP(2,40)     ,FT(2,40)     A        48
     9      ,FU(2,40)   ,IAOL(2,40)  ,INDR(2,40)   ,FL(2,40,25),CANO1          A        49
     *      ,B          ,N                                                     A        50
      REAL   RAY        ,RAYS(25)    ,RAY2         ,RR           ,MUUT(40)     DRAG      4
     *      ,MA(40)     ,MU          ,MUS(25)      ,MU0(25)      ,MU2          DRAG      5
     *      ,MA(25)     ,MA2         ,MASM         ,MABM1        ,MMBM         DRAG      6
     * ,      MAP                                                              DRAG      7
      COMMON/P11/XMOMV(8), XMOMP(8),ENEP1(8),REP(40,8),V(40,8),R(40,8),        DRAG      8
     1V2(40,8), R2(40,8), IRADY(8), TP(40,8), TP2(40,8), RP(8),                DRAG      9
     2RMP(40,8), RMP2(40,8) ,ENEP2(8),NBL(8),UM(40)                            DRAG     10


     3,VOLP(8),AIP(8),MC(8),DENG(40,8),ICUND(40,8)                             DRAG     11
      COMMON/P12/FFF,FFG,GAMA,UM1,PU,NPG,RMX,DNDSP(8)                          DRAG     12
       COMMON/P13/CL,CS,TPS,RHSS,R1,RTRAN,SIG,EP,IPANT,IRINE,TR(40)            DRAG     13
     1 ,SUMP,SUMPV,SUMPE                                                       DRAG     14
      COMMON/CFF/IPTU                                                          DRAG     15
      COMMON/XYZ/IXYZ,JXYZ                                                     DRAG     16
      IXYZ=5                                                                   DRAG     17
      JXYZ=0                                                                   DRAG     18
      KZZ=N                                                                    DRAG     19
      N=K-1                                                                    DRAG     20
       GAMP1=GAMA+1.                                                           DRAG     21
      SQGAM=SQRT(GAMA)                                                         DRAG     22
      SQTPI=1.7724                                                             DRAG     23
      DO 1 J=1, NPG                                                            DRAG     24
      IF (N.GT. NBL(J) ) GO TO 6                                               DRAG     25
    2 CONTINUE                                                                 DRAG     26
      AXX1=    ((U(K)-R(K,J))**2 +V(K,J)**2)                                   DRAG     27
      AXX= SQRT(AXX1)                                                          DRAG     28
      UM(K)=0.0                                                                DRAG     29
      DO7 I=1,NUS                                                              DRAG     30
    7 UM(K)=UM(K)+XS(I,K)*MU0(I)*(T(K)/T0(I))**OMEGA(I)                        DRAG     31
C        CALCULATE DRAG COEFFICIENT                                            DRAG     32
      REP(K,J)=RHO(K)*AXX*RP(J)*2.0/UM(K)                                      25SEP1    4
      MAP= MA(K)*AXX/U (K)                                                     DRAG     34
      RMM=MAP/REP(K,J)                                                         DRAG     35
      CDO=24./REP(K,J)                                                         DRAG     36
      IF (REP(K,J).GE.60.) CDO=0.40                                            DRAG     37
      TANG=2.*ALOG(MAP)                                                        DRAG     38
      TANY=(EXP( 2.*TANG)-1.)/(EXP(2.*TANG)+1.)                                DRAG     39
      CD1=.86+.26*TANY+.17*EXP(-2.5*(ALOG(MAP)/1.4)**2)                        DRAG     40
      IF(MAP.LT..3) CD1=.40                                                    DRAG     41
      CDO=1.0                                                                  DRAG     42
      CD=CD1                                                                   DRAG     43
      XRN=1.26 * SQGAM*RMM                                                     DRAG     44
      IF (XRN.GT.4.) GO TO 4                                                   DRAG     45
      IF (XRN .LT. 1.E-8) GO TO 5                                              DRAG     46
      XX1=XRN**0.4                                                             DRAG     47
      XX2=EXP(1.2* XRN**0.5)                                                   DRAG     48
      GRN=XX1*XX2/(1.0+XX1*XX2)                                                DRAG     49
      XX3=XRN**0.6                                                             DRAG     50
      XX4=EXP(XRN)                                                             DRAG     51
      DRE=1.0-EXP(-XX3*XX4*(CDO-.4)*REP(K,J)/8.)                               DRAG     52
      CDR=GRN*DRE                                                              DRAG     53
    4 CONTINUE                                                                 DRAG     54
      S1=SQRT(.5*GAMA)*MAP                                                     DRAG     55
      S2=S1*S1                                                                 DRAG     56
      S3=S2*S1                                                                 DRAG     57
      S4=S3*S1                                                                 DRAG     58
      S32=S2**.5                                                               DRAG     59
      SQ=S1*SQRT(T (K)  /TP(K,J))                                              DRAG     60
      CDFM= EXP(-S32)*(1.0+2.0*S2)/SQTPI/S3  .                                 DRAG     61
     1     +(4.0*(S4+S2)-1.0)/2.0/S4*ERF(S1)                                   DRAG     62
     2   +0.667*SQTPI/SQ                                                       DRAG     63
      CD=CDR*(CDFM-CD1)+CD1                                                    DRAG     64
    5 FQ=CD/24.*REP(K,J)*FFF                                                   DRAG     65
C        CALCULATE NUSSELT NUMBER                                              DRAG     66
      XNU= 2.0+ 0.459*(REP(K,J)  **0.55)*(PU**0.33)                            DRAG     67


      XX5= 5.0*(GAMA**1.5)*RMM/GAMP1/PU*XNU                                    DRAG     68
      XNUF= XNU/(1.0+XX5)                                                      DRAG     69
      XUF= XNUF*(GAMP1/GAMA*REP(N,J)*PU*EXP(-0.5/RMM))                         DRAG     70
      UP= 0.5*XUF*FFG                                                          DRAG     71
      XX7 = 4.5 * UM(K) * FQ / (RHSS*RP(J)*RP(J))                              DRAG     72
      XMOMV(J) = XX7*V(K-1,J)                                                  DRAG     73
      XMOMP(J) = XX7 * (U (K)-R(K-1,J))                                        DRAG     74
      ENEP1(J)= XX7  *AXX1                                                     DRAG     75
      RF=GAMA/GAMP1*(2.+.67*EXP(-MAP**2./3.)    )                              DRAG     76
      RCL=0.0                                                                  DRAG     77
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```
      DO 20 I=1,NOS                                                     FLUX  24
   20 ZJ(I,K)=0.0                                                       FLUX  25
      GO TO 10000                                                       FLUX  26
C     ----- SETUP OF AVERAGED FLUX QUANTITIES NEEDED -----              FLUX  27
   30 YCMBAR=YBBAR                                                      FLUX  28
      TBBAR=TABAR                                                       FLUX  29
      TBBAR=TABAR                                                       FLUX  30
      HMBBAR=HMABAR                                                     FLUX  31
      DO 50 I=1,NOS                                                     FLUX  32
      CBBAR(I)=CABAR(I)                                                 FLUX  33
   50 XBBAR(I)=XABAR(I)                                                 FLUX  34
      PBBAR=PABAR                                                       FLUX  35
      NUV=NOO                                                           FLUX  36
      IF (IFLAG) 100,400,100                                            FLUX  37
  100 YABAR=.5*(Y(K+1)+Y2(K+1))                                         FLUX  38
      TABAR=.5*(T(K+1)+T2(K+1))                                         FLUX  39
      NU=K+1                                                            FLUX  40
      UBAR(NU)=SQRT(.5*(U(K+1)**2+U2(K+1)**2))                          FLUX  41
      HMABAR=.5*(HMU(K+1)+HMU2(K+1))                                    FLUX  42
  110 HAVG=0.25*(H(K)+H(K-1)+H2(K)+H2(K-1))                             FLUX  43
      HAVG=0.25*(H(K+1)+H(K)+H2(K+1)+H2(K))                             FLUX  44
  130 ZM=Z0=0.0                                                         FLUX  45
      DO 200 I=1,NOS                                                    FLUX  46
      CABAR(I)=.5*(C(I,K+1)+C2(I,K+1))                                  FLUX  47
  200 ZM=ZM+CABAR(I)/WM(I)                                              FLUX  48
      ZM=1.0/ZM                                                         FLUX  49
      DO 300 I=1,NOS                                                    FLUX  50
  300 XABAR(I)=CABAR(I)*ZM/WM(I)                                        FLUX  51
      PABAR=.5*(P(K+1)+P2(K+1))                                         FLUX  52
      GO TO 605                                                         FLUX  53
  400 TABAR=T(K+1)                                                      FLUX  54
      NU=K+1                                                            FLUX  55
      UBAR(NU)=U(K+1)                                                   FLUX  56
      HMABAR=HMU(K+1)                                                   FLUX  57
  420 HAVG=.5*(H(K)+H(K-1))                                             FLUX  58
      HAVG=.5*(H(K+1)+H(K))                                             FLUX  59
      DO 500 I=1,NOS                                                    FLUX  60
      CABAR(I)=C(I,K+1)                                                 FLUX  61
  500 XABAR(I)=XS(I,K+1)                                                FLUX  62
      PABAR=P(K+1)                                                      FLUX  63
  605 CALL TRANSP(TABAR,PABAR,K+1,MULT,IB16)                            FLUX  64


C     ----- CALCULATION OF HEAT FLUX AND SHEAR -----                    FLUX  65
      QE=(FUB(HDOT(K+1)+HDOT(K))/(HMABAR*UBAR(K+1)*HAVG**DELTA*MU*HMBBAR FLUX  66
     1 *UBAR(K)*HAVG**DELTA*RZ))/(2.0*DELTA*PI)                         FLUX  67
      FF(K)=(HDOT(K+1)+HDOT(K))/(HMABAR*UBAR(K+1)*HAVG**DELTA*RAY*      FLUX  68
     1  HMBBAR*UBAR(K)*HAVG**DELTA*RAY2)/(2.0*DELTA*PI)                 FLUX  69
      TAU(K)=(UBAR(K+1)-UBAR(K))/(FNUMU                                 FLUX  70
      Q(K)=(TABAR-TBBAR)/(FNUM)                                         FLUX  71
C     ----- CALCULATION OF MASS FLUX -----                              FLUX  72
      DO 1900 I=1,NOS                                                   FLUX  73
      CDENOM(I)=(HDOT(K)+HDOT(K+1))/(HMBBAR**2*D2IM(I,2)*UBAR(K)*PI*(2.0 FLUX  74
     1 *HAVG)**DELTA+HMABAR**2*DIM(1,2)*UBAR(K+1)*PI*(2.0*HAVG)**DELTA) FLUX  75
 1900 ZJ(I,K)=(CABAR(I)-CBBAR(I))/CDENOM(I)                             FLUX  76
      IF(ISHOCK.NE.1) GO TO 1925                                        FLUX  77
      IF(XFAX.GT.XFL) GO TO 1925                                        FLUX  78
      NOS=1                                                             FLUX  79
 1925 L=1                                                               FLUX  80
      DIST=X(L)+XL                                                      FLUX  81
      IF (ABS(DIST)-FRAC*YU) 1850,10000,10000                           FLUX  82
 1850 FLIP=1-ABS(DIST)/(FRAC*YU)                                        FLUX  83
      Q(K)=Q(K)*FLIP                                                    FLUX  84
      TAU(K)=TAU(K)*FLIP                                                FLUX  85
      DO 1835 I=1,NOS                                                   FLUX  86
 1835 ZJ(I,K)=ZJ(I,K)*FLIP                                              FLUX  87
10000 RETURN                                                            FLUX  88
      END                                                               FLUX  89


      SUBROUTINE LOCATE(XM,YO,X1,Y1,X2,Y2,X3,Y3,IFG000)                 LOCATE   2
      RETURN                                                            LOCATE   3
      END                                                               LOCATE   4


      SUBROUTINE MATE7(IDIM,NN,MM,A,B,DET,IND,NOGO)                     MATE7    2
CSIMEQ            SOLVES THE EQUATION AX=B WHERE A,X, AND B ARE MATRICES MATE7   3
C                         WHERE                                         MATE7    4
C        IDIM     IS A FIXED POINT CONSTANT OR VARIABLE WHOSE VALUE     MATE7    5
C                 MUST BE EQUAL TO THE MAXIMUM VALUE THAT MAY EVER BE   MATE7    6
C                 ASSUMED BY THE SUBSCRIPT I OF THE MATRIX A(I,J). THIS MATE7    7
C                 VALUE IS IDENTICAL WITH THAT USED IN THE DIMENSION    MATE7    8
C                 STATEMENTS WHEN SETTING THE UPPER LIMIT OF THE        MATE7    9
C                 SUBSCRIPT.                                            MATE7   10
C        N        IS A FIXED POINT VARIABLE OR CONSTANT WHOSE VALUE     MATE7   11
C                 MUST EQUAL THE NUMBER OF ROWS IN THE MATRIX A.        MATE7   12
C        MM       IS A FIXED POINT VARIABLE OR CONSTANT WHOSE VALUE     MATE7   13
C                 MUST EQUAL THE NUMBER OF COLUMNS IN THE MATRIX B.     MATE7   14
C        A        IS THE SOURCE PROGRAM FLOATING POINT VARIABLE USED TO MATE7   15
C                 DESIGNATE THE ELEMENTS OF MATRIX A.                   MATE7   16
C        B        IS THE SOURCE PROGRAM FLOATING POINT VARIABLE USED TO MATE7   17
C                 DESIGNATE THE ELEMENTS OF MATRIX B.                   MATE7   18
C        DET      MUST BE A FLOATING POINT VARIABLE WHOSE VALUE SERVES  MATE7   19
C                 AS A SCALE FACTOR BY WHICH SIMEQ MULTIPLIES THE VALUE MATE7   20
C                 OF THE DETERMINANT OF A. AFTER THE EXECUTION OF THIS  MATE7   21
      DIMENSION A(IDIM,1),B(IDIM,1),IND(1)                              MATE7   22
C                 SUBROUTINE, DET CONTAINS THE SCALED VERSION OF THE    MATE7   23
C                 DETERMINANT.                                          MATE7   24
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C        IND     MUST BE A FIXED OR FLOATING POINT VARIABLE DESIGNATING
C                A ONE-DIMENSIONAL ERASABLE ARRAY OF LENGTH AT LEAST
C                EQUAL TO THE NUMBER OF ROWS IN MATRIX A. IT IS IN THIS
C                AREA SIMEQ KEEPS A RECORD OF THE COLUMN PERMUTATIONS.
C        NEGO    IS A FIXED POINT VARIABLE WHICH WILL BE ASSIGNED THE
C                FIXED POINT CONSTANTS.
C                    1 IF THE SOLUTION WAS SUCCESSFUL.
C                    3 IF THE MATRIX A WAS SINGULAR.
C                            DIMENSIONS
C        A       IDIM X ICIM     IF MM IS LESS THAN OR EQUAL TO IDIM
C                IDIM X MM       IF MM IS GREATER THAN IDIM
C        B       IDIM X MM
C        IND     IDIM
C                            NOTE
C                FOR MATRICES THE ROW DIMENSION MUST BE THE SAME AS
C                THAT GIVEN ABOVE. THE COLUMN DIMENSION MUST AT LEAST
C                BE THAT GIVEN ABOVE.
      NNNN
C                FOR THE VECTOR THE DIMENSION MUST AT LEAST BE THAT
C                GIVEN ABOVE
C                EXECUTION OF THIS ROUTINE DESTROYS THE ORIGINAL A AND
C                B MATRICES
C                AFTER A SUCCESSFUL EXIT FROM THIS SUBROUTINE, THE
C                ANSWERS OR THE X MATRIX REPLACE THE A MATRIX.
C                THIS REPLACEMENT IS DONE ACCORDING TO THE SCHEME.
C                         A(I,J) IS REPLACED BY X(I,J) .
      NNNN
C        SET INITIAL CONSTANTS
      NEGO=1
C        SPECIAL CONSIDERATION WHEN THE ORDER OF MATRIX A IS 1.
      IF(N.NE.1) GO TO 5
      IF (A(1,1).EQ.0.) GO TO 110
      HOLD=A(1,1)
      DO 1 I=1,M


    1 A(1,I)=B(1,I)/HOLD
      DET=DET*HOLD
      RETURN
    5 NM1=N-1
      NP1=N+1
C        INITIALIZE DETERMINANT
      DET=1.
C        INITIALIZE COLUMN INDICATORS
      DO 5 I=1,N
    5 IND(I)=I
C        BEGIN TRIANGULARIZATION TO GET UPPER   IANGLE
      DO 70 K=1,NM1
      KP1=K+1
      KR=K
      KC=K
C        SEARCH FOR PIVOTAL ELEMENT
      BIGA=ABS(A(K,K))
      DO 10 I=K,N
      DO 10 J=K,N
      IF(BIGA.GE.ABS(A(I,J))) GO TO 10
      BIGA=ABS(A(I,J))
      KR=I
      KC=J
   10 CONTINUE
C        TEST FOR SINGULAR MATRIX
      IF(BIGA.EQ.0.) GO TO 110
C        UPDATE DETERMINANT
      DET=DET*A(KR,KC)
C        INTERCHANGE ROWS
      IF(KR.EQ.K) GO TO 30
      DO 20 I=K,N
      HOLD=A(K,I)
      A(K,I)=A(KR,I)
   20 A(KR,I)=HOLD
C        INTERCHANGE ELEMENTS OF RIGHT HAND SIDES
      DO 25 L=1,M
      HOLD=B(K,L)
      B(K,L)=B(KR,L)
   25 B(KR,L)=HOLD
C        CHANGE SIGN OF DETERMINANT DUE TO ROW INTERCHANGE
      DET=-DET
C        INTERCHANGE COLUMNS
   30 IF(KC.EQ.K) GO TO 55
      DO 45 J=1,N
      HOLD=A(J,K)
      A(J,K)=A(J,KC)
   45 A(J,KC)=HOLD
C        INTERCHANGE COLUMN INDICATORS
      I=IND(K)
      IND(K)=IND(KC)
      IND(KC)=I
C        CHANGE SIGN OF DETERMINANT DUE TO COLUMN INTERCHANGE
      DET=-DET
C        DIVIDE REDUCED EQUATION-ON, BY LEADING ELEMENT
   55 DO 60 I=KP1,N
   60 A(K,I)=A(K,I)/A(K,K)
      DO 65 L=1,M


   65 B(K,L)=B(K,L)/A(K,K)
C        REDUCE MATRIX AND RIGHT HAND SIDES
      DO    I=KP1,N
      DO    J=KP1,N
```

```
C         IND      MUST BE A FIXED OR FLOATING POINT VARIABLE DESIGNATING
C                  A ONE-DIMENSIONAL ERASABLE ARRAY OF LENGTH AT LEAST
C                  EQUAL TO THE NUMBER OF ROWS IN MATRIX A. IT IS IN THIS
C                  AREA SIMEQ KEEPS A RECORD OF THE COLUMN PERMUTATIONS.
C         NOGO     IS A FIXED POINT VARIABLE WHICH WILL BE ASSIGNED THE
C                  FIXED POINT CONSTANTS.
C                     1 IF THE SOLUTION WAS SUCCESSFUL.
C                     3 IF THE MATRIX A WAS SINGULAR.
C                              DIMENSIONS
C         A        IDIM X IDIM     IF MM IS LESS THAN OR EQUAL TO IDIM
C                  IDIM X MM       IF MM IS GREATER THAN IDIM
C         B        IDIM X MM
C         IND      IDIM
C                              NOTE
C                  FOR MATRICES THE ROW DIMENSION MUST BE THE SAME AS
C                  THAT GIVEN ABOVE. THE COLUMN DIMENSION MUST AT LEAST
C                  BE THAT GIVEN ABOVE.
       ****
C                  FOR THE VECTOR THE DIMENSION MUST AT LEAST BE THAT
C                  GIVEN ABOVE
C                  EXECUTION OF THIS ROUTINE DESTROYS THE ORIGINAL A AND
C                  B MATRICES.
C                  AFTER A SUCCESSFUL EXIT FROM THIS SUBROUTINE, THE
C                  ANSWERS OR THE X MATRIX REPLACE THE A MATRIX.
C                  THIS REPLACEMENT IS DONE ACCORDING TO THE SCHEME,
C                              A(I,J) IS REPLACED BY X(I,J) .
       ****
C         SET INITIAL CONSTANTS
      NOGO=1
C         SPECIAL CONSIDERATION WHEN THE ORDER OF MATRIX A IS 1.
      IF(N.NE.1) GO TO 3
      IF (A(1,1).EQ.0.) GO TO 110
      HOLD=A(1,1)
      DO 1 I=1,M

    1 A(1,I)=B(1,I)/HOLD
      DET=DET*HOLD
      RETURN
    3 NM1=N-1
      NP1=N+1
C         INITIALIZE DETERMINANT
      DETM=DET
C         INITIALIZE COLUMN INDICATORS
      DO 5 I=1,N
    5 IND(I)=I
C         BEGIN TRIANGULARIZATION TO GET UPPER TRIANGLE
      DO 70 K=1,NM1
      KP1=K+1
      KR=K
      KC=K
C         SEARCH FOR PIVOTAL ELEMENT
      BIGA=ABS(A(K,K))
      DO 10 I=K,N
      DO 10 J=K,N
      IF(BIGA.GE.ABS(A(I,J))) GO TO 10
      BIGA=ABS(A(I,J))
      KR=I
      KC=J
   10 CONTINUE
C         TEST FOR SINGULAR MATRIX
      IF(BIGA.EQ.0.) GO TO 110
C         UPDATE DETERMINANT
      DETM=DETM*A(KR,KC)
C         INTERCHANGE ROWS
      IF(KR.EQ.K) GO TO 30
      DO 20 I=K,N
      HOLD=A(K,I)
      A(K,I)=A(KR,I)
   20 A(KR,I)=HOLD
C         INTERCHANGE ELEMENTS OF RIGHT HAND SIDES
      DO 25 L=1,M
      HOLD=B(K,L)
      B(K,L)=B(KR,L)
   25 B(KR,L)=HOLD
C         CHANGE SIGN OF DETERMINANT DUE TO ROW INTERCHANGE
      DETM=-DETM
C         INTERCHANGE COLUMNS
   30 IF(KC.EQ.K) GO TO 55
      DO 40 J=1,N
      HOLD=A(J,K)
      A(J,K)=A(J,KC)
   40 A(J,KC)=HOLD
C         INTERCHANGE COLUMN INDICATORS
      I=IND(K)
      IND(K)=IND(KC)
      IND(KC)=I
C         CHANGE SIGN OF DETERMINANT DUE TO COLUMN INTERCHANGE
      DETM=-DETM
C         DIVIDE REDUCED EQUATION-ON, BY LEADING ELEMENT
   55 DO 60 J=KP1,N
   60 A(K,J)=A(K,J)/A(K,K)
      DO 65 L=1,M

   65 B(K,L)=B(K,L)/A(K,K)
C         REDUCE MATRIX AND RIGHT HAND SIDES
      DO 70 I=KP1,N
      DO 65 J=KP1,N
```

```
   65 A(I,J)=A(I,J)-A(I,K)*A(K,J)                                          MATE7   120
      DO 70 L=1,M                                                          MATE7   121
   70 B(I,L)=B(I,L)-A(I,K)*B(K,L)                                          MATE7   122
C        FINAL TEST FOR SINGULAR MATRIX                                    MATE7   123
      IF(A(N,N).EQ.0.) GO TO 110                                           MATE7   124
C        COMPUTE FINAL DETERMINANT                                         MATE7   125
      DET=DET*A(N,N)                                                       MATE7   126
C        BACK SUBSTITUE TO OBTAIN SOLUTION VECTORS                         MATE7   127
      DO 80 L=1,M                                                          MATE7   128
      B(N,L)=B(N,L)/A(N,N)                                                 MATE7   129
      DO 80 I=1,NN                                                         MATE7   130
      HOLD=0.                                                              MATE7   131
      J=N-I                                                                MATE7   132
      DO 75 KC=1,I                                                         MATE7   133
      K=NP1-KC                                                             MATE7   134
   75 HOLD=HOLD+A(J,K)*B(K,L)                                              MATE7   135
   80 B(J,L)=B(J,L)-HOLD                                                   MATE7   136
C        REARRANGE SOLUTION VECTORS TO ORIGINAL ORDER                      MATE7   137
      DO 90 I=1,N                                                          MATE7   138
      J=IRO(I)                                                             MATE7   139
      DO 90 L=1,M                                                          MATE7   140
   90 A(J,L)=B(I,L)                                                        MATE7   141
      RETURN                                                               MATE7   142
C        SINGULAR MATRIX = REDUNDANT SET OF EQUATIONS                      MATE7   143
  110 NOGO=1                                                               MATE7   144
      DET=0.                                                               MATE7   145
      RETURN                                                               MATE7   146
      END                                                                  MATE7   147


      SUBROUTINE ORTHOG(SIDE,LIM1,LIM2)                                    ORTHOG    2
      RETURN                                                               ORTHOG    3
      END                                                                  ORTHOG    4


      SUBROUTINE PBNDY                                                     PBNDY     2
      COMMON A(25,7)      ,AA(40)      ,ALFA(25,25),ALPHAM     ,ALPHAP     A         2
     1       ,ATOL        ,BETAP       ,BMIX       ,C11(25)    ,C(25,40)   A         3
     2       ,C12(25)     ,C2(25,40)   ,CABAR(25)  ,CHHAR(25)  ,CP         A         4
     3       ,CPS(25)     ,CPSH        ,CSH(25)    ,CSH1(25)   ,CSTREM(25) A         5
     4       ,CXSTRM      ,D21N(25,25) ,DEFF(25)   ,D2EFF(25)  ,DELTA      A         6
     5       ,D11         ,DELSS(40)   ,DELS       ,DELSU      ,DLS(40)    A         7
     6       ,D1M(25,25)  ,D12         ,DELY(40)   ,D13        ,DPDY(40)   A         8
     7       ,D14         ,DPHIDS(40)  ,EPCON                              A         9
     8       ,EPSLON      ,EXTRA(50)   ,FSTEP      ,FMAX       ,GRAD       A        10
     9       ,H11         ,H(40)       ,HH         ,HJ         ,HPM(25)    A        11
     *       ,H2PM(25)    ,H3PM(25)    ,ICONST     ,ICOUNT     ,IDENT(25)  A        12
     1       ,IERROR      ,IEXTRA(50)  ,IFLAG      ,IKIND                  A        13
     2       ,IFIUC       ,ISHOCK      ,ITYPE      ,IPD                    A        14
     3       ,IDIFF       ,K           ,KAY        ,KAYS       ,KAY2       A        15
     4       ,KLO         ,KMAX                                            A        16
     5       ,KUP         ,KP          ,LL         ,LPLANE     ,MA         A        17
     6       ,MASH        ,MDOT        ,MMAX       ,MUO        ,MU         A        18
     7       ,MU2         ,MUS         ,MW         ,MW2        ,MWSH       A        19
     8       ,NBOUND      ,NUS         ,NITER      ,NMAX       ,NN         A        20
      COMMON NOCASE       ,OMEGA(25)   ,P11        ,P(40)      ,P12        A        21
     1       ,P2(40)                   ,PB(50)     ,PABAR      ,PBBAR      A        22
     2       ,PHS         ,P15         ,PH1(40)                ,PH10(50)   A        23
     3       ,PHISH1      ,PHSTRM                  ,PHIF(50)   ,P18        A        24
     4       ,PHI2(40)    ,PHIBS       ,PI         ,PM(25)     ,PSH        A        25
     5       ,PSH1        ,PS1         ,PSTREM                 ,PW(50)     A        26
     6       ,Q11         ,Q(40)       ,QXTW1      ,QXTW2                  A        27
     7       ,QW(50)      ,R11         ,R(40)                  ,R0(50)     A        28
     8       ,R05         ,R13         ,RBAR(40)   ,R14        ,R2(40)     A        29
     9       ,RCON        ,R15         ,RE(40)     ,RESH       ,R16        A        30
     *       ,RHO(40)     ,R17         ,RHO2(40)   ,RHS(25)    ,RHSEN      A        31
     1       ,RHSHOW      ,RHABAR      ,RHBBAR     ,RO         ,RSH        A        32
     2       ,RSTREM      ,RV          ,R19        ,RW(100)    ,S          A        33
     3                    ,SP(50)      ,SC(25)                 ,SW(50)     A        34
     4       ,S13         ,SX(40)      ,T11        ,T(40)      ,T12        A        35
     5       ,T2(40)      ,TABAR       ,TBBAR      ,T0(25)     ,T14        A        36
     6       ,TAW(40)     ,TXTW1       ,TXTW2      ,TOL        ,TSH        A        37
     7       ,TSH1        ,TSTREM                  ,TW(50)     ,TWS        A        38
     8       ,TS          ,U11         ,U(40)      ,U12        ,U2(40)     A        39
      COMMON UXTW1        ,UXTW2       ,U14        ,UBAR(40)   ,USH        A        40
     1       ,USH1        ,USTREM                  ,UW(50)     ,UWS        A        41
     2       ,X11         ,X(40)       ,X12        ,X2(40)                 A        42
     3       ,XW(50)      ,XWS         ,XABAR(25)  ,XBBAR(25)  ,X15        A        43
     4       ,XS(25,40)   ,XSH         ,XSTREM                 ,XW(50)     A        44
     5       ,YPW(40)                  ,Y11        ,Y(40)      ,Y12        A        45
     6       ,Y2(40)      ,YABAR       ,YBBAR      ,Z4(25)     ,Z11(25)    A        46
     7       ,Z3(25,40)   ,ZPW         ,S2X        ,W2SH       ,X2SH       A        47
     8       ,FX(2,40)    ,FK(2,40)    ,FPHI(2,40) ,FP(2,40)   ,FT(2,40)   A        48
     9       ,FU(2,40)    ,INDL(2,40)  ,INDR(2,40) ,FC(2,40,25),CARD1      A        49
     *       ,W           ,N                                               A        50
      REAL    KAY         ,KAYS(25)    ,KAY2       ,KW         ,MDOT(40)   PBNDY     4
     *       ,MA(40)      ,MO          ,MUS(25)    ,MUO(25)    ,MU2        PBNDY     5
     *       ,MW(25)      ,MW2         ,MASH       ,MASH1      ,MWSH       PBNDY     6
     *  ,      KAP                                                         PBNDY     7
      COMMON/PT1/XNOWL(8), XNOWR(8),ENEP1(8),KEP(40,8),V(40,8),R(40,8),    PBNDY     8
     1V2(40,8), R2(40,8), IBODY(8), IP(40,8), IP2(40,8), RP(8),            PBNDY     9
     2RMP(40,8), RMP2(40,8) ,ENEP2(8),NNL(8),UM(40)                        PBNDY    10


     3,VOLF(8),STP(8),HC(8),LENG(40,8),ICOND(40,8)                         PBNDY    11
      COMMON/PT2/FFF,FFG,GAMA,GMI,PO,NPG,KMX,DNDSP(8)                      PBNDY    12
      COMMON/PT3/CL,CS,IPS,RHSS,AT,HIRAN,SIG,EP,IPART,INTNE,IR(40)         PBNDY    13
     1 ,SUPP,SUPPS,SUPPT                                                   PBNDY    14
      COMMON/AXYZ/IXYZ,JXYZ                                                PBNDY    15
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      IXTZ=0                                                            PBNDY   16
      JAYZ=0                                                            PBNDY   17
      KMX=0                                                             PBNDY   18
      DO 5 J=1, NPG                                                     PBNDY   19
      NBLJ=NBL(J)                                                       PBNDY   20
      NBL1=NBLJ+1                                                       PBNDY   21
      UNDSP(J)= UNDSP(J)+ DLS(NBL1)*V2(NBLJ,J)/R2(NBLJ,J)               PBNDY   22
      TRBDY(J)= Y2(NBL1 )+UNDSP(J)                                      PBNDY   23
      DO 12 IEM=1,MMAX                                                  PBNDY   24
      IF (TRBDY(J) .LT. Y2(IEM+1)) GO TO 15                             PBNDY   25
   12 CONTINUE                                                          PBNDY   26
      WRITE(6,103)                                                      PBNDY   27
   15 CONTINUE                                                          PBNDY   28
      IF (IEM.NE.NBL(J)) UNDSP(J)=TRBDY(J)-Y2(IEM+1)                    PBNDY   29
      IF (IEM.GT.KMX) KMX=IEM                                           PBNDY   30
      DO 14 LK=1,IEM                                                    PBNDY   31
      IF (LK.GT.NBL(J)) GO TO 17                                        PBNDY   32
      GO TO 16                                                          PBNDY   33
   17 R2(LK,J)=R2(LK-1,J)                                               PBNDY   34
      V2(LK,J)=V2(LK-1,J)                                               PBNDY   35
      IP2(LK,J)=IP2(LK-1,J)                                             PBNDY   36
      RMP2(LK,J)= RMP2(LK-1,J)                                          PBNDY   37
   16 CONTINUE                                                          PBNDY   38
      V(LK,J)= V2(LK,J)                                                 PBNDY   39
      R(LK,J)= R2(LK,J)                                                 PBNDY   40
      IP(LK,J)=IP2(LK,J)                                                PBNDY   41
   11 RMP(LK,J)= RMP2(LK,J)                                             PBNDY   42
   14 CONTINUE                                                          PBNDY   43
      NBL(J)=IEM                                                        PBNDY   44
    5 CONTINUE                                                          PBNDY   45
      WRITE (6,102) S,(TRBDY(J),J=1,NPG)                                PBNDY   46
  102 FORMAT( 1H ,33H BOUNDARY OF PARTICLE PHASE AT S= ,F11.5, 1P8E11.3) PBNDY   47
  103 FORMAT(41H  *******NO PARTICLES IN THIS FLOW FIELD  //)           PBNDY   48
      RETURN                                                            PBNDY   49
      END                                                               PBNDY   50

      SUBROUTINE PPUTIN                                                 PPUTIN   2
      COMMON A(25,7),     ,AA(40)       ,ALFA(25,25),ALPHAM    ,ALPHAP   A       2
     1        ,ATOL        ,BETAP        ,BETA        ,C11(25)   ,C(25,40)  A       3
     2        ,C12(25)     ,C2(25,40)    ,CABAR(25)   ,CHBAR(25) ,CP       A       4
     3        ,CPS(25)     ,CPSH         ,CSH(25)     ,CSH1(25)  ,CSTREM(25) A     5
     4        ,CXSTRM      ,D21P(25,25)  ,DEFF(25)    ,D2EFF(25) ,DELTA    A       6
     5        ,D11         ,DELSS(40)    ,DELS        ,DELSO     ,DLS(40)  A       7
     6        ,DIM(25,25)  ,D12          ,DELY(40)    ,D13       ,DPDY(40) A       8
     7        ,D14         ,DPHIDS(40)   ,EPCON                              A       9
     8        ,EPSLON      ,EXTRA(50)    ,ESTEP       ,FMAX      ,GRAD     A      10
     9        ,H11         ,H(40)        ,HH          ,HJ        ,HPM(25)  A      11
     *        ,H2PM(25)    ,H3PM(25)     ,ICONST      ,ICOUNT    ,IDENT(25) A     12
     1        ,IERROR      ,IEXTRA(50)   ,IFLAG       ,IKIND               A      13
     2        ,IPIOL       ,ISHOCK       ,ITYPE       ,IPD                 A      14
     3        ,IDIFF       ,K            ,KAY         ,KAYS      ,KAY2     A      15
     4        ,KLO         ,KMAX                                           A      16
     5        ,KOP         ,KK           ,LL          ,LPLANE    ,MA       A      17
     6        ,MASH        ,MDOT         ,MMAX        ,MOO       ,MU       A      18
     7        ,MU2         ,MUS          ,MR          ,MW2       ,MWSH     A      19
     8        ,NBOUND      ,NDS          ,NITER       ,NMAX      ,NN       A      20
      COMMON NUCASE       ,OMEGA(25)    ,P11         ,P(40)     ,P12      A      21
     1        ,P2(40)                    ,PO(50)      ,PABAR     ,PBBAR    A      22
     2        ,PHS         ,P15          ,PHI(40)               ,PHIH(50) A      23
     3        ,PHISH1      ,PHSTRM                    ,PHIW(50)  ,P16      A      24
     4        ,PHI2(40)    ,PHIBS        ,PI          ,PR(25)    ,PSH      A      25
     5        ,PSH1        ,PSI          ,PSTREM                ,PW(50)   A      26
     6        ,Q11         ,Q(40)        ,QXIR1       ,QXIR2               A      27
     7        ,QW(50)      ,R11          ,R(40)                 ,RH(50)   A      28
     8        ,RBS         ,R13          ,RBAR(40)    ,R14       ,R2(40)   A      29
     9        ,RCON        ,R15          ,RE(40)      ,RESH      ,R16      A      30
     *        ,RHO(40)     ,R17          ,RHO2(40)    ,RHS(25)   ,RHSEN    A      31
     1        ,RHSHOK      ,RHABAR       ,RHBBAR      ,RO        ,RSH      A      32
     2        ,RSTREM      ,RV           ,R19         ,RA(100)   ,S        A      33
     3                     ,SH(50)       ,SL(25)                ,SW(50)   A      34
     4        ,S13         ,SX(40)       ,T11         ,T(40)     ,T12      A      35
     5        ,T2(40)      ,TABAR        ,TBBAR       ,TO(25)    ,T14      A      36
     6        ,TAW(40)     ,TXIR1        ,TXIR2       ,TOL       ,TSH      A      37
     7        ,TSH1        ,TSTREM                    ,TW(50)    ,TWS      A      38
     8        ,TS          ,U11          ,U(40)       ,U12       ,U2(40)   A      39
      COMMON UXIR1        ,UXIR2        ,U14         ,UBAR(40)  ,USH      A      40
     1        ,USH1        ,USTREM                    ,UW(50)    ,UWS      A      41
     2        ,X11         ,X(40)        ,X12         ,X2(40)              A      42
     3        ,XB(50)      ,XBS          ,XABAR(25)   ,XBBAR(25) ,X15      A      43
     4        ,XS(25,40)   ,XSH          ,XSTREM                ,XW(50)   A      44
     5        ,ZHAA(40)                  ,Y11         ,Y(40)     ,Y12      A      45
     6        ,Y2(40)      ,YABAR        ,YBBAR       ,ZA(25)    ,Z11(25)  A      46
     7        ,ZJ(25,40)   ,ZMF          ,S2X         ,R2SH      ,X2SH     A      47
     8        ,FA(2,40)    ,FR(2,40)     ,FPHI(2,40)  ,FP(2,40)  ,FT(2,40) A      48
     9        ,FU(2,40)    ,INDL(2,40)   ,INDR(2,40)  ,FC(2,40,25),CARD1   A      49
     *        ,M           ,N                                              A      50
      REAL     KAY         ,KAYS(25)     ,KAY2        ,KK        ,MOUT(40) PPUTIN   4
     *        ,MA(40)      ,MU           ,MUS(25)     , MO(25)   ,MU2      PPUTIN   5
     *        ,MW(25)      ,MW2          ,MASH        ,MASH1     ,MASH     PPUTIN   6
     *         MAP                                                        PPUTIN   7
      COMMON/PT1/XMOMV(8), XMOMP(8),ENEP1(8),REP(40,8),V(40,8),R(40,8),  PPUTIN   8
     1V2(40,8), R2(40,8), TRBDY(8), IP(40,8), IP2(40,8), RP(8),          PPUTIN   9
     2RMP(40,8), RMP2(40,8) ,ENEP2(8),FRL(8),UM(40)                      PPUTIN  10

     3,VOLP(8),ATP(8),RL(8),DLNG(40,8),ICOND(40,8)                      PPUTIN  11
      COMMON/PT2/FFF,FFG,GAMA,OMI,PO,NPG,KMX,UNDSP(8)                   PPUTIN  12
      COMMON/PT3/CL,CS,TPS,RHSS,PT,HTRAN,SIG,EP,IPART,IKIND,IR(40)      PPUTIN  13
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     1 ,SUMP,SUMPV,SUMPE
      COMMON/XYZ/IXYZ,JXYZ
      DIMENSION VI(6),AI(6),TPI(6),RHPI(6)   ,DENGI(6)
      NAMELIST/NAM1/ FFF,FFG,UMI    ,CL,CS,TPS,RHOS,AT,HTRAN,SIG,EP,NPG,
     1 NC,KMA,RP,AI,VI,TPI,RHPI
      IXYZ=11
      JXYZ=0
      READ  (5,100) FFF,FFG,CL,CS,HTRAN,AT
      READ (5,100) RHOS,SIG,EP      ,TPS    ,UMI
      READ(5,107) NPG,NC
      READ (5,107) (NBL(J),J=1,NPG)
      DO 25 J=1,NPG
   25 NBL(J)=NBL(J)-1
      KMA=NBL(1)
      IF (NPG.LE.1) GO TO 245
      DO 241 J=2,NPG
      IF (KMA.LT.NBL(J)) KMA=NBL(J)
  241 CONTINUE
  245 CONTINUE
      READ (5,100) (RP(J),J=1,NPG)
      IF(NC.EQ.1) GO TO 2
      READ(5,100) (AI(J),J=1,NPG)
      READ(5,100) (VI(J),J=1,NPG)
      READ(5,100) (TPI(J),J=1,NPG)
      READ(5,100) (RHPI(J),J=1,NPG)
      READ(5,100) (DENGI(J),J=1,NPG)
      DO 5 J=1,NPG
      KMA=NBL(J)
      DO 4 K=1,KMA
      A(K,J)=AI(J)
      V(K,J)=(K-1)*VI(J)/(KMA-1)
      TP(K,J)=TPI(J)
      RHP(K,J)=RHPI(J)
      DENG(K,J)=DENGI(J)
      A2(K,J)=A(K,J)
      V2(K,J)=V(K,J)
      TP2(K,J)=TP(K,J)
      RHP2(K,J)=RHP(K,J)
    4 CONTINUE
      CROSP(J)=0.0
      IRBDY(J)=Y(KMA+1)
    5 CONTINUE
      DO 21 J=1, NPG
      KMA=NBL(J)
      DO 21 K=1,KMA
      ICOND(K,J)=0
   21 CONTINUE
      GO TO 3
    2 CONTINUE
      DO 1 K=1,KMA
      READ (5,100) (A(K,J),J=1,NPG)
      READ (5,100) (V(K,J),J=1,NPG)
      READ (5,100) (TP(K,J),J=1,NPG)
      READ (5,100) (RHP(K,J),J=1,NPG)
      READ(5,107) (ICOND(K,J),J=1,NPG)
      READ(5,100) (DENG(K,J),J=1,NPG)
      DO 6 J=1,NPG
      A2(K,J)=A(K,J)
      V2(K,J)=V(K,J)
      TP2(K,J)=TP(K,J)
      RHP2(K,J)=RHP(K,J)
    6 CONTINUE
    1 CONTINUE
      READ( 5,100) (IRBDY(J),J=1,NPG)
      READ( 5,100) (CROSP(J),J=1,NPG)
    3 CONTINUE
      WRITE(6,NAM1)
      DO 7 J=1, NPG
      VOLP(J)=1.333333*PI*(RP(J)**3)
      WTP(J)=VOLP(J)*RHOS
    7 HC(J)=WTP(J)    *HTRAN
      DO 12 J=1,NPG
      IF (KMAX-NBL(J)) 12,12,11
   11 KMA1=NBL(J)+1
      DO 10 K=KMA1,KMAX
      A(K,J)=0.0
      V(K,J)=0.0
      TP(K,J)=0.0
      RHP(K,J)=0.0
      A2(K,J)=0.0
      V2(K,J)=0.0
      TP2(K,J)=0.0
      RHP2(K,J)=0.0
      DENG(K,J)=0.0
      ICOND(K,J)=1
   10 CONTINUE
   12 CONTINUE
      DO 22 K=1,KMAX
      WRITE(6,101) K
      WRITE(6,102) ( A(K,J),J=1,NPG)
      WRITE(6,103) ( V(K,J),J=1,NPG)
      WRITE(6,105) ( TP(K,J),J=1,NPG)
      WRITE(6,106) ( RHP(K,J),J=1,NPG)
   22 CONTINUE
  100 FORMAT(8E10.3)
  101 FORMAT(1H ,15HSTREAMLINE NO.  ,I5)
  102 FORMAT(1H ,19HDOWNSTREAM VELOCITY ,2X,1P8E12.3)
  103 FORMAT(1H ,21HCROSS-STREAM VELOCITY ,1P8E12.3)
  105 FORMAT(1H ,20HPARTICLE TEMPERATURE ,1X,1P8E12.3)
  106 FORMAT(1H ,16HPARTICLE DENSITY ,5X,1P8E12.3)
  107 FORMAT(8I5)
      RETURN
      END
```

```
      SUBROUTINE PART                                                     PART       2
      COMMON A(25,7)    ,AA(40)      ,ALFA(25,25),ALPHAM    ,ALPHAP       A          2
     1       ,ATOL       ,BETAP       ,BMIX        ,C11(25)    ,C(25,40)    A          3
     2       ,C12(25)    ,C2(25,40)   ,CABAR(25)   ,CBBAR(25)  ,CP          A          4
     3       ,CPS(25)    ,CPSH        ,CSH(25)     ,CSH1(25)   ,CSTHEM(25)  A          5
     4       ,MASTHM     ,D2IM(25,25),DEFF(25)     ,D2EFF(25)  ,DELTA       A          6
     5       ,D11        ,DELSS(40)   ,DELS        ,DELSU      ,DLS(40)     A          7
     6       ,DIM(25,25) ,D12         ,DELY(40)    ,D13        ,DPBY(40)    A          8
     7       ,D14        ,DPHIDS(40)  ,EPCON                                A          9
     8       ,EPSLON     ,EXTRA(50)   ,FSTEP       ,FMAX       ,GRAD        A         10
     9       ,H11        ,H(40)       ,HH          ,HJ         ,HPM(25)     A         11
     *       ,H2PM(25)   ,H3PM(25)    ,ICCNBT      ,ICOUNT     ,IDENT(25)   A         12
     1       ,IERROR     ,IEXTRA(50)  ,IFLAG       ,IKIND                   A         13
     2       ,IPTUC      ,ISHOCK      ,ITYPE       ,IPD                     A         14
     3       ,IDIFF      ,K           ,KAY         ,KAYS       ,KAY2        A         15
     4       ,KLO        ,KMAX                                              A         16
     5       ,KUP        ,KN          ,LL          ,LPLANE     ,MA          A         17
     6       ,MASH       ,MDOT        ,MMAX        ,MU0        ,MU          A         18
     7       ,MU2        ,MUS         ,MW          ,MW2        ,MWSH        A         19
     8       ,NBOUND     ,NDS         ,NITER       ,NMAX       ,NN          A         20
      COMMON NUCASE     ,OMEGA(25)   ,P11         ,P(40)      ,P12         A         21
     1       ,P2(40)                  ,PB(50)      ,PABAR      ,PBBAR       A         22
     2       ,PBS        ,P15         ,PHI(40)                 ,PHIN(50)    A         23
     3       ,PHISH1     ,PHSTRM                   ,PHIW(50)   ,P18         A         24
     4       ,PHI2(40)   ,PHIBS       ,PI          ,PR(25)     ,PSH         A         25
     5       ,PSH1       ,PSI         ,PSTREM                  ,PW(50)      A         26
     6       ,Q11        ,Q(40)       ,QXTR1       ,QXTR2                   A         27
     7       ,QW(50)     ,R11         ,R(40)                   ,RH(50)      A         28
     8       ,RHS        ,R13         ,RHAR(40)    ,R14        ,R2(40)      A         29
     9       ,RCON       ,R15         ,RE(40)      ,RESH       ,R16         A         30
     *       ,RHO(40)    ,R17         ,RHO2(40)    ,RHS(25)    ,RHSEN       A         31
     1       ,RHSHOM     ,RHABAR      ,RHBBAR      ,RU         ,RSH         A         32
     2       ,RSTHEM     ,RV          ,R19         ,RW(100)    ,S           A         33
     3                   ,SH(50)      ,SC(25)                  ,SW(50)      A         34
     4       ,S13        ,SX(40)      ,T11         ,T(40)      ,T12         A         35
     5       ,T2(40)     ,TABAR       ,TBBAR       ,TU(25)     ,T14         A         36
     6       ,TAW(40)    ,TXTR1       ,TXTR2       ,TUC        ,TSH         A         37
     7       ,TSH1       ,TSTREM                   ,TW(50)     ,TWS         A         38
     8       ,TS         ,U11         ,U(40)       ,U12        ,U2(40)      A         39
      COMMON UXTR1      ,UXTR2       ,U14         ,UBAR(40)   ,USH         A         40
     1       ,USH1       ,USTHEM                   ,UW(50)     ,UWS         A         41
     2       ,X11        ,X(40)       ,X12         ,X2(40)                  A         42
     3       ,XW(50)     ,XBS         ,XABAR(25)   ,XBBAR(25)  ,X15         A         43
     4       ,XS(25,40)  ,XSH         ,XSTREM                  ,XW(50)      A         44
     5       ,ZMRK(40)                ,Y11         ,Y(40)      ,Y12         A         45
     6       ,Y2(40)     ,YABAR       ,YBBAR       ,ZA(25)     ,Z11(25)     A         46
     7       ,ZJ(25,40)  ,ZMA         ,S2X         ,R2SH       ,X2SH        A         47
     8       ,FX(2,40)   ,FR(2,40)    ,FPHI(2,40)  ,FP(2,40)   ,FT(2,40)    A         48
     9       ,FU(2,40)   ,INOL(2,40)  ,INOR(2,40)  ,FC(2,40,25),CARD1       A         49
     *       ,F          ,N                                                 A         50
      REAL   KAY        ,KAYS(25)    ,KAY2        ,KN         ,MDOT(40)    PART       4
     *       ,MA(40)     ,MU          ,MUS(25)     ,MUU(25)    ,MU2         PART       5
     *       ,MW(25)     ,MW2         ,MASH        ,MASH1      ,MWSH        PART       6
     *           MAP                                                      PART       7
      COMMON/PT1/XMOMV(8), XMOMP(8),ENEP1(8),HEP(40,8),V(40,8),W(40,8),   PART       8
     1V2(40,8), W2(40,8), TRBDY(8), TP(40,8), TP2(40,8), RP(8),           PART       9
     2RHP(40,8), RHP2(40,8) ,ENEP2(8),NBL(8),UM(40)                       PART      10


     3,VOLP(8),WTP(8),MC(8),DENG(40,8),ICOND(40,8)                        PART      11
      COMMON/P12/FFF,FFG,GAMA,UMI,PU,NPG,KMX,DNDSP(8)                     PART      12
       COMMON/P13/CL,CS,TFS,RHSS,RT,HIRAN,SIG,EP,IPART,IKINE,IR(40)       PART      13
     1 ,SUMP,SUMPV,SUMPT                                                  PART      14
      COMMON/XYZ/IXYZ,JXYZ                                                PART      15
      IXYZ=12                                                             PART      16
      JXYZ=0                                                              PART      17
      K=K-1                                                               PART      18
      KZZ=K                                                               PART      19
      N=K+1                                                               PART      20
      DEL=(DLS(K)+DLS(K-1))*.5                                            PART      21
      DO 1 J=1, NPG                                                       PART      22
      IF (K.GT. NBL(J)) GO TO 3                                           PART      23
    2 CONTINUE                                                            PART      24
      XXG=DEL *V(K,J)/W(K,J)                                              PART      25
      IF(K.EQ.1) GO TO 13                                                 PART      26
      K1=K-1                                                              PART      27
      RX1= (.5*(R(K1+1)+R(K1)))**DELTA                                    PART      28
      RX2=(.5*(R(K1+2)+R(K1+1)))**DELTA                                   PART      29
      DELLY=SQRT((X(K1+2)-X(K1))**2+(R(K1+2)-R(K1))**2)*.5                PART      30
      THEN=(PHI(K1+2)-PHI(K1))/DELLY *.5                                  PART      31
      DWDN=(W(K1+1,J)-W(K1,J))/DELLY                                      PART      32
      DVDN=(V(K1+1,J)-V(K1,J))/DELLY                                      PART      33
      DTDN=(TP(K1+1,J)-TP(K1,J))/DELLY                                    PART      34
      DRRVDN=(RX2  *RHP(K1+1,J)*V(K1+1,J)                                 PART      35
     1 -RX1  *RHP(K1,J)*V(K1,J))/DELLY                                    PART      36
      GO TO 16                                                            PART      37
   13 DVDN=0.0                                                            PART      38
      DELLY=SQRT(R(2)**2+(X(2)-X(1))**2)  *.5                             PART      39
      DVDN=V(1,J)/DELLY                                                   PART      40
       DTDN=0.0                                                           PART      41
      DRRVDN=RHP(1,J)*V(1,J)/DELLY*(R(2)/2.)**DELTA                       PART      42
      THEN=PHI(2)/(2.*DELLY)                                              PART      43
   16 THES=(PHI2(K)+PHI2(K-1)-PHI(K)-PHI(K-1))/(DLS(K)+DLS(K-1))          PART      44
      W2(K,J)=W(K,J)-XXG*DWDN                                             PART      45
     1        +XXG*V(K,J)*THEN                                            PART      46
     2        +DEL *V(K,J)*THES +XMOMP(J)*DEL /W(K,J)                     PART      47
      V2(K,J)= V(K,J)- XXG*DVDN                                           PART      48
     1        - DEL *V(K  J)*THEN                                         PART      49
     2        - W(K,J)*DEL *THES                                          PART      50
     3        - XMOMV(J)*DEL /W(K,J)                                      PART      51
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C     ENERGY EQUATION                                                    PART      52
      CC=CL                                                              PART      53
      IF(TP(K,J).LE.TPS) CC=CS                                           PART      54
      IF (ICOND(K,J).EQ.0) GO TO 14                                      PART      55
      XX8= -TP(J)*ENEP2(J)          *DEL /R(K,J)/MJ                      PART      56
      XX9=-4.0*PI*RP(J)*RP(J)*EP*SIG*(TPS**4.0)/R(K,J)*DEL/MJ            PART      57
      DENG(K,J)=DENG(K,J)+XX8+XX9                                        PART      58
      IF (ABS(DENG(K,J)).GE.HC(J)) GO TO 15                              PART      59
      GO TO 12                                                           PART      60
   15 CONTINUE                                                           PART      61
      ICOND(K,J)=0                                                       PART      62
      WRITE (6,102) RP(J),S,K,DENG(K,J)                                  PART      63
   14 CONTINUE                                                           PART      64
      XX8=HEP2(J)/MJ/V(K,J)/CC                                           PART      65
      XX9=     EP*SIG*3.0/(R(K,J)   *RP(J)*RHOS*CC) *(TP(K,J)**4.0)/MJ   PART      66
      TP2(K,J)= TP(K,J)-XX8*DTDN -(XX8+XX9)*DEL                          PART      67


      IF (((TP2(K,J)-TPS)*(TP(K,J)-TPS)).GE.0.0) GO TO 12                PART      68
      ICOND(K,J)=1                                                       PART      69
      TP2(K,J)=TPS                                                       PART      70
      WRITE (6,103) RP(J),S,K                                            PART      71
  103 FORMAT (1H ,1PE10.3,43H CM PARTICLE  GROUP START SOLIDIFYING AT S= PART      72
     1,0PF10.4,19H CM STREAMTUBE NO. ,I5/)                               PART      73
   12 CONTINUE                                                           PART      74
C        CONTINUITY EQUATION                                             PART      75
      RX1=(.5*(R(K+1)+R(K)))**DELTA                                      PART      76
      R2X1=(.5*(R2(K+1)+R2(K)))**DELTA                                   PART      77
      XX10=RX1 *RMP(K,J)*U(K,J)                                          PART      78
      XX11=RX1 *RMP(K,J)*V(K,J)                                          PART      79
      RMP2(K,J)= 1.0/(R2X1 *U2(K,J))*(XX10*(1.0-DEL *THEN)               PART      80
     1      -DRRVDN*DEL                                                  PART      81
     2          + XX11*THES*DEL )                                        PART      82
      GO TO 1                                                            PART      83
    3 V2(K,J)=0.0                                                        PART      84
      U2(K,J)=0.0                                                        PART      85
      TP2(K,J)=0.0                                                       PART      86
      RMP2(K,J)= 0.0                                                     PART      87
      HEP(K,J)=0.0                                                       PART      88
    1 CONTINUE                                                           PART      89
  102 FORMAT (1H ,1PE10.3,40H CM SIZE PARTICLE GROUP SOLIDIFIED AT S= ,  PART      90
     1 0PF10.4,19H CM  STREAMTUBE NO. ,I5, 3X,1PE10.3,3HCAL /)           PART      91
      K=K+1                                                              PART      92
      N=K22                                                              PART      93
      RETURN                                                             PART      94
      END                                                                PART      95


      SUBROUTINE PUTOUT(IOUT)                                            PUTOUT     2
      COMMON A(25,7)     ,AA(40)      ,ALFA(25,25),ALPHAN    ,ALPHAP     A          2
     1       ,ATOL       ,BETAP       ,BPIX       ,C11(25)   ,C(25,40)   A          3
     2       ,C12(25)    ,C2(25,40)   ,CABAR(25)  ,CHBAR(25) ,CP         A          4
     3       ,CPS(25)    ,CPSH        ,CSH(25)    ,CSH1(25)  ,CSTREM(25) A          5
     4       ,MASTRP     ,D2IN(25,25),DEFF(25)    ,D2EFF(25) ,DELTA      A          6
     5       ,D11        ,DELSS(40)   ,DELS       ,DELSO     ,DLS(40)    A          7
     6       ,DIN(25,25) ,D12         ,DELY(40)   ,D13       ,DPDY(40)   A          8
     7       ,D14        ,GPHIDS(40)  ,EPCON                             A          9
     8       ,EPSLON     ,EXTRA(50)   ,FSTEP      ,FMAX      ,GRAD       A         10
     9       ,H11        ,H(40)       ,HH         ,HJ        ,HPH(25)    A         11
     *       ,H2PH(25)   ,H3PH(25)    ,ICONST     ,ICOUNT    ,IDENT(25)  A         12
     1       ,IERROR     ,IEXTRA(50)  ,IFLAG      ,IKIND                 A         13
     2       ,IPTOC      ,ISHOCK      ,ITYPE      ,IPD                   A         14
     3       ,IDIFF      ,K           ,KAY        ,KAYS      ,KAY2       A         15
     4       ,KLO        ,KMAX                                           A         16
     5       ,KUP        ,KK          ,LL         ,LPLANE    ,MA         A         17
     6       ,MASH       ,MOUT        ,MMAX       ,MU0       ,MU         A         18
     7       ,MU2        ,MUS         ,MA         ,MA2       ,MASH       A         19
     8       ,NROUND     ,NOS         ,NITER      ,NMAX      ,NN         A         20
      COMMON NUCASE      ,OMEGA(25)   ,P11        ,P(40)     ,P12        A         21
     1       ,P2(40)                  ,PB(50)     ,PABAR     ,PBBAR      A         22
     2       ,PHS        ,P15         ,PHI(40)               ,PHIB(50)   A         23
     3       ,PHISH1     ,PHSTRM                  ,PHIN(50)  ,P18        A         24
     4       ,PHI2(40)   ,PHIBS       ,PI         ,PR(25)    ,PSH        A         25
     5       ,PSH1       ,PS1         ,PSTREM                ,PW(50)     A         26
     6       ,U11        ,U(40)       ,UXTR1      ,UXTR2                 A         27
     7       ,RB(50)     ,R11         ,R(40)                 ,RR(50)     A         28
     8       ,RHS        ,R13         ,RHAR(40)   ,R14       ,R2(40)     A         29
     9       ,RCON       ,R15         ,RE(40)     ,RESH      ,R16        A         30
     *       ,RHO(40)    ,R17         ,RHO2(40)   ,RHS(25)   ,RHSEN      A         31
     1       ,RHSPOR     ,RHABAR      ,RHBBAR     ,RO        ,RSH        A         32
     2       ,RSTREP     ,RV          ,R19        ,RP(100)   ,S          A         33
     3                   ,SH(50)      ,SC(25)                ,SW(50)     A         34
     4       ,S13        ,SX(40)      ,T11        ,T(40)     ,T12        A         35
     5       ,T2(40)     ,TABAR       ,TBBAR      ,T0(25)    ,T14        A         36
     6       ,TAR(40)    ,TXTR1       ,TXTR2      ,TOL       ,TSH        A         37
     7       ,TSH1       ,TSTREM                  ,TW(50)    ,TWS        A         38
     8       ,TS         ,U11         ,U(40)      ,U12       ,U2(40)     A         39
      COMMON UXTR1       ,UXTR2       ,U14        ,UHAR(40)  ,USH        A         40
     1       ,USH1       ,USTREM                  ,UW(50)    ,UWS        A         41
     2       ,X11        ,X(40)       ,X12        ,X2(40)                A         42
     3       ,XB(50)     ,XBS         ,XABAR(25)  ,XBBAR(25) ,X15        A         43
     4       ,XS(25,40)  ,XSH         ,XSTREM                ,XW(50)     A         44
     5       ,ZBAR(40)                ,Y11        ,Y(40)     ,Y12        A         45
     6       ,Y2(40)     ,YABAR       ,YBBAR      ,ZA(25)    ,Z11(25)    A         46
     7       ,ZJ(25,40)  ,ZPR         ,S2X        ,R2SH      ,X2SH       A         47
     8       ,FX(2,40)   ,FR(2,40)    ,FPHI(2,40) ,FP(2,40)  ,FT(2,40)   A         48
     9       ,FU(2,40)   ,INDL(2,40)  ,INDR(2,40) ,FC(2,40,25),CARD1     A         49
     *       ,N          ,N                                              A         50
      REAL   KAY         ,KAYS(25)    ,KAY2       ,KA        ,MOUT(40)   PUTOUT     4
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*         ,MA(40)       ,MU            ,MUS(25)      ,MUO(25)     ,MU2          PUTOUT     5
*         ,MO(25)       ,MM2           ,MASM         ,MASM1       ,MMSM         PUTOUT     6
*  ,       MAP                                                                  PUTOUT     7
      COMMON/PT1/XMOMV(8), XMOMP(8),ENEP1(8),REP(40,8),V(40,8),W(40,8),        PUTOUT     8
     1V2(40,8), R2(40,8), TRUDY(8), TP(40,8), TP2(40,8), RP(8),                 PUTOUT     9
     2RHP(40,8), RHP2(40,8) ,ENEP2(8),NOL(8),UM(40)                             PUTOUT    10


     3,VOLP(8),WTP(8),MC(8),DENS(40,8),ICOND(40,8)                              PUTOUT    11
      COMMON/PT2/FFF,FFG,GAMA,UMI,PO,NPG,KMX,DNDSP(8)                           PUTOUT    12
      COMMON/PT3/CL,LS,TPS,RHSS,RT,HTRAN,SIG,EP,IPART,INIAF,TR(40)              PUTOUT    13
     1 ,SUMP,SUMPV,SUMFE                                                        PUTOUT    14
      COMMON/CHEM1/ ZID(5), INR(40),IRT(40),NC(40,3),INNR(40,5),               PUTOUT    15
     1 AV,CM(26,26),FI(26),WP(26),                                              PUTOUT    16
     2 WM(26),WDOT(26,40),CSI(26),QX(26)                                        PUTOUT    17
      COMMON/SHOPUT/ XSHN,RSHN,PSIK,PSHG,TSHN,USHN,CSHN(25)                     PUTOUT    18
      COMMON/CFF/IPTO                                                           PUTOUT    19
      COMMON/XYZ/IXYZ,JXYZ                                                      PUTOUT    20
      COMMON/BLFG/ INLFLG,IBL                                                   25SEPT     9
      COMMON/WALL/ TWALL                                                        25SEPT    10
      COMMON/BLOUT/ REXI,THETAI,CFI,UFI,CFCCFI,H12,DISP,THETAC(2),DELTI,        PUTOUT    22
     *DELTAC,CFC,QWALL,TAUWAL,ETA(140),TETC(140),UOUFI(140),YDELI(140)          PUTOUT    23
      DIMENSION SUMI(25)                                                        PUTOUT    24
      DATA I01/4HCO  /                                                          PUTOUT    25
      DATA I02/4HCO2 /                                                          PUTOUT    26
      DATA I03/4HH2O /                                                          PUTOUT    27
      DATA I04/4HHCL /                                                          PUTOUT    28
      DATA I05/4HN2  /                                                          PUTOUT    29
      DATA I06/4HH2  /                                                          PUTOUT    30
      DATA I07/4HE   /                                                          PUTOUT    31
      IXYZ=13                                                                   PUTOUT    32
      JXYZ=0                                                                    PUTOUT    33
      GO TO (50,1300,10), IOUT                                                  PUTOUT    34
   10 L=K                                                                       PUTOUT    35
      GO TO 250                                                                 PUTOUT    36
   50 L=1                                                                       PUTOUT    37
      SUMDOT=0.0                                                                PUTOUT    38
      DO 75 I=1,NOS                                                             PUTOUT    39
   75 SUMI(I)=0.0                                                               PUTOUT    40
      WRITE (6,100) LL,X2(L),R2(L),PHI2(L)                                      PUTOUT    41
  100 FORMAT ( 1H0,I5,8X,3HX=,   E11.4,3X,3HR=,   E11.4,3X,5HPHI=,              PUTOUT    42
     *E11.4)                                                                    PUTOUT    43
      L=2                                                                       PUTOUT    44
  250 IF(LL) 225,260,260                                                        PUTOUT    45
  225 WRITE(6,300) L,X(L),R(L),PHI(L),T(L),P(L),U(L)                            PUTOUT    46
      GO TO 325                                                                 PUTOUT    47
  260 WRITE (6,300) L,X2(L),R2(L),PHI2(L),T2(L),P2(L),U2(L)                     PUTOUT    48
  300 FORMAT(1H0,5X,I5,3X,2HX=,1P1E11.4,4X,2HR=,1P1E11.4,4X,4HPHI=,1P1E1        PUTOUT    49
     *1.4,2X,2HT=,1P1E11.4,4X,2HP=,1P1E11.4,4X,2HU=,1P1E11.4)                   PUTOUT    50
  325 HTK=H(L)+U(L)**2/(2.0*HJ)                                                 PUTOUT    51
      PTK=P(L)+RHO(L)*U(L)**2/(2.0*BETAP)                                       PUTOUT    52
      SUMDOT=SUMDOT+MDOT(L)                                                     PUTOUT    53
  375 IF(LL) 350,360,360                                                        PUTOUT    54
  350 WRITE (6,400) MA(L),DELY(L),H(L),HTK,TAW(L),Q(L),PTK,RHO(L),SX(L)         PUTOUT    55
     *,SUMDOT                                                                   PUTOUT    56
  400 FORMAT(14X,3HMA=,   E11.4,3X,5HDELY=,   E11.4,1X,2HH=,   E11.4,4X,        PUTOUT    57
     *3HHT=,   E11.4,3X,4HTAW=,   E11.4,2X,2HQ=,   E11.4 / 14X,3HPT=,           PUTOUT    58
     *E11.4,3X,4HRHO=,   E11.4,2X,3HSX=,   E11.4,3X,7HSUMDOT=,   E11.4          PUTOUT    59
     *)                                                                         PUTOUT    60
      GO TO 410                                                                 PUTOUT    61
  360 WRITE (6,400) MA(L),DELY(L),H(L),HTK,TAW(L),Q(L),PTK,RHO2(L),SX(L)        PUTOUT    62
     *,SUMDOT                                                                   PUTOUT    63
      IF(L.LT.KMAX) GO TO 410                                                   PUTOUT    64
      WRITE (6,1001)                                                            PUTOUT    65
 1001 FORMAT (///12H(***)////)                                                  PUTOUT    66


      IF(IBL.EQ.0) GO TO 408                                                    25SEPT    11
      WRITE(6,1007) TWALL                                                       25SEPT    12
 1007 FORMAT (50X,17HWALL TEMPERATURE=,1X,F5.0,1X,6HKELVIN///)                  25SEPT    13
      WRITE (6,1002)                                                            PUTOUT    67
 1002 FORMAT (50X,25HBOUNDARY LAYER PARAMETERS///)                              25SEPT    14
      WRITE (6,1003) REXI,DELTI,THETAI,CFI,UFI,DISP,DELTAC,THETAC(2),           PUTOUT    69
     *CFC,CFCCFI,H12,QWALL,TAUWAL                                               PUTOUT    70
 1003 FORMAT (T5,*RES= *,E11.4,T24,*DELTAI= *,E11.4,T46,*THETAI= *,             PUTOUT    71
     1E11.4,T66,*CFI= *,E11.4,T87,*UFI= *,E11.4/                                PUTOUT    72
     2T5,*DISP= *,E11.4,T24,*DELTAC= *,E11.4,T46,*THETAC= *,E11.4,              PUTOUT    73
     3T66,*CFC= *,E11.4,T87,*CFC/CFI= *E11.4/                                   PUTOUT    74
     4T5,*H12= *,E11.4,T24,*QWALL= *,E11.4,T46,*TAUWALL= *,E11.4)               PUTOUT    75
      IF(INLFLG) 1004,410,1004                                                  PUTOUT    76
 1004 WRITE (6,1005)                                                            PUTOUT    77
 1005 FORMAT (///T53,*BOUNDARY LAYER PROFILES*///T26,*U/UE*,T47,                PUTOUT    78
     1*  T/TE*,T67,*U/UF INC*,T88,*Y/DEL*)                                      PUTOUT    79
      WRITE (6,1006) (ETA(J),TETC(J),UOUFI(J),YDELI(J),J=5,140,5)               PUTOUT    80
 1006 FORMAT (T25,E11.4,T45,E11.4,T65,E11.4,T85,E11.4)                          PUTOUT    81
  408 WRITE(6,409)                                                              25SEPT    15
  409 FORMAT (45X,27HBOUNDARY LAYER NOT COMPUTED///)                            25SEPT    16
  410 WRITE (6,1000)                                                            PUTOUT    82
 1000 FORMAT(1H0)                                                               PUTOUT    83
      IF (NOS-1) 450,450,1050                                                   PUTOUT    84
 1050 DO 1299 I=1,NOS                                                           PUTOUT    85
      IF (IEXTRA(I)) 1120,1110,1120                                             PUTOUT    86
 1110 IF (LL) 1105,1115,1115                                                    PUTOUT    87
 1105 WRITE (6,1200) IDENT(I),C(I,L),XS(I,L),WDOT(I,L)                          PUTOUT    88
      GO TO 1299                                                                PUTOUT    89
 1115 WRITE (6,1200) IDENT(I),C2(I,L),XS(I,L),WDOT(I,L)                         PUTOUT    90
 1200 FORMAT(14X,6HSPECIE,2X, A4,7X,2HC=,   E11.4,4X,2HX=,   E11.4,4X,          PUTOUT    91
     * 5HWDOT=,E11.4)                                                           PUTOUT    92
      GO TO 1299                                                                PUTOUT    93
```

```
1120 SUMI(I)=SUMI(I)+MDOT(L)*C(I,L)
1150 IF (LL) 1125,1160,1160
1125 WRITE (6,1225) IDENT(I),C(I,L),XB(I,L),MDOT(I,L),SUMI(I),ZJ(I,L)
1225 FORMAT(14X,6HSPECIE,2X, A6,7X,2HC=,1P1E11.4,4X,2HX=,1P1E11.4,4X,
   * 5HMDOT=,E11.4,3X,3HFI=,
   *1P1E11.4,3X,3HZJ=,1P1E11.4)
     GO TO 1299
1160 WRITE (6,1225) IDENT(I),C2(I,L),XS(I,L),MDOT(I,L),SUMI(I),ZJ(I,L)
1299 CONTINUE
 450 IF (IPTO .EQ. 0) GO TO 457
     XL=X2(L)/REX
     RL=R2(L)/REX
     I22=25
     I23=25
     I24=25
     I25=25
     I26=25
     I27=25
     DO 60 J=1,NOS
     IF (IDENT(J) .EQ. 101) I21=J
     IF (IDENT(J) .EQ. 102) I22=J
     IF (IDENT(J) .EQ. 103) I23=J
     IF (IDENT(J) .EQ. 104) I24=J
     IF (IDENT(J) .EQ. 105) I25=J
     IF (IDENT(J) .EQ. 106) I26=J

     IF (IDENT(J) .EQ. 107) I27=J
  60 CONTINUE
     ENE=0.733E22*P2(L)/T2(L)*C2(I27,L)
     VEE=6.21E5*SQRT(T(L))
     SMG=C2(I21,L)*(2.06E-23*VEE+2.46E-16)+C2(I22,L)*4.7E-8/VEE+C2(I23,
    1L)*5.9/(VEE**2)+C2(I24,L)*1.85/(VEE*VEE)+C2(I25,L)*3.29E-23*VEE+
    2C2(I26,L)*(1.45E-23*VEE+8.9E-16)
     ENUE=4.57E27*P2(L)/SQRT(T2(L))*SMG
     SGM=7.14509E-4*ENE/ENUE
     IF(IPTO.GT.4) GO TO 61
     WRITE (6,1400) XL,RL,ENE,ENUE,SGM
1400 FORMAT (2X,6HX/REX=,1PE11.4,5X,6HR/REX=,E11.4,5X,3HNE=,E11.4,5X,
   1 4HNUE=,E11.4,5X,6HSIGMA=,E11.4)
     IF (IPTO .EQ. 1 .OR. IPTO .EQ. 3)
    1WRITE (7,1600) XL,RL,ENE,ENUE,SGM
1600 FORMAT (4E19.12/3E19.12)
     IF (IPTO .EQ. 2 .OR. IPTO .EQ. 4)
    1WRITE (8,1601) XL,RL,ENE,ENUE,SGM
1601 FORMAT (7E19 [illegible]
  61 WRITE (6, [illegible] XL,T2(L),P2(L),XS(I22,L),XS(I23,L),XS(I21,L)
1500 FORMAT (5X,6 [illegible] X=,1PE11.4,5X,6HR/REX=,E11.4,4X,2HT=,E11.4,9X,
   1 2HP=,E11.4/1 [illegible] (CO2)=,E11.4,6X,6H(H2O)=,E11.4,7X,5H(CO)=,E11.4)
     IF (IPTO .EQ. 5 . R. IPTO .EQ. 3)
    1WRITE (7,160 [illegible] XL,RL,T2(L),P2(L),XS(I22,L),XS(I23,L),XS(I21,L)
     IF (IPTO [illegible] 6 .OR. IPTO .EQ.3)
    1WRITE [illegible] XL,RL,T2(L),P2(L),XS(I22,L),XS(I23,L),XS(I21,L)
 457 IF ( [illegible] ,600,600
 500 L=L [illegible]
     GO TO 250
1300 IF (NBOUND) 1320,1310,1320
1310 K=1
     DELPHI=PHI(K)-PHISH
     WRITE (6,1401) LL,K,X2(K),R2(K),PHI2(K),PSIK,DELPHI
     K=2
     GO TO 600
1320 DELPHI=PHI(KMAX)-PHISH
     WRITE (6,1401) LL,KMAX,X(KMAX),R(KMAX),PHI(KMAX),PSI,DELPHI
1401 FORMAT (1H0,5HSHOCK,2X,3HLL=,I4,2X,2HK=,I2,2X,2HX=,1P1E11.4,2X,2HR
    *=,1P1E11.4,2X,4HPHI=,1P1E11.4,2X,4HPSI=,1P1E11.4,2X,7HDELPHI=,1P1E
    *11.4)
 600 RETURN
     END
```

```
      SUBROUTINE PPTOUT(KKKK)
      COMMON A(25,7)       ,AA(40)       ,ALFA(25,25),ALPHAN    ,ALPHAP
     1       ,ATOL         ,BETAP        ,BMIX       ,C11(25)   ,C(25,40)
     2       ,C12(25)      ,C2(25,40)    ,CAHAR(25)  ,CBHAR(25) ,CP
     3       ,CPS(25)      ,CPSH         ,CSH(25)    ,CSH1(25)  ,CSTHEM(25)
     4       ,VISTM        ,D2IM(25,25)  ,DEFF(25)   ,D2EFF(25) ,DELTA
     5       ,D11          ,DELSS(40)    ,DELS       ,DELSO     ,DLS(40)
     6       ,DIM(25,25)   ,D12          ,DELY(40)   ,D13       ,DPDY(40)
     7       ,D14          ,DPHIDS(40)   ,EPCON
     8       ,EPSLON       ,EXTRA(50)    ,FSTEP      ,FMAX      ,GRAD
     9       ,H11          ,H(40)        ,HH         ,HJ        ,HPM(25)
     *       ,H2PM(25)     ,H3PM(25)     ,ICONST     ,ICOUNT    ,IDENT(25)
     1       ,IERROR       ,IEXTRA(50)   ,IFLAG      ,IKIND
     2       ,IPTOC        ,ISHOCK       ,ITYPE      ,IPD
     3       ,IUIFF        ,K            ,KAY        ,KAYS      ,KAY2
     4       ,KLL          ,KMAX
     5       ,KOP          ,KK           ,LL         ,LPLANE    ,MA
     6       ,MASH         ,MDOT         ,MMAX       ,MUO       ,MU
     7       ,MU2          ,MUS          ,MW         ,MW2       ,MWSH
     8       ,NBOUND       ,NOS          ,NITER      ,NMAX      ,NN
      COMMON NUCASE        ,OMEGA(25)    ,P11        ,P(40)     ,P12
     1       ,P2(40)                     ,PH(50)     ,PWBAR     ,PHHAW
```

```
     2     ,PHS       ,P15       ,PHI(40)              ,PHIN(50)  A      23
     3     ,PHISHI    ,PHSTRM               ,PHIW(50) ,P18        A      24
     4     ,PHI2(40)  ,PHINS     ,PI        ,PN(25)    ,PSH       A      25
     5     ,PSHI      ,PSI       ,PSTREM              ,PW(50)     A      26
     6     ,Q11       ,Q(40)     ,QXTR1     ,QXTR2                A      27
     7     ,QW(50)    ,R11       ,R(40)               ,RW(50)     A      28
     8     ,RHS       ,R13       ,RBAR(40)  ,R14      ,R2(40)     A      29
     9     ,RCON      ,R15       ,RE(40)    ,RESH     ,R16        A      30
     *     ,RHO(40)   ,R17       ,RHO2(40)  ,RHS(25)  ,RHSEN      A      31
     1     ,RHSMUM    ,RHABAR    ,RHOBAR    ,RU       ,RSH        A      32
     2     ,RSTREM    ,RV        ,R19       ,RW(100)  ,S          A      33
     3.               ,SB(50)    ,SC(25)              ,SW(50)     A      34
     4     ,S12       ,SX(40)    ,T11       ,T(40)    ,T12        A      35
     5     ,T2(40)    ,TABAR     ,TBBAR     ,TO(25)   ,T14        A      36
     6     ,TAW(40)   ,TXTR1     ,TXTR2     ,TOL      ,TSH        A      37
     7     ,TSHI      ,TSTREM               ,TW(50)   ,TWS        A      38
     8     ,TS        ,U11       ,U(40)     ,U12      ,U2(40)     A      39
      COMMON UXTR1    ,UXTR2     ,U14       ,UBAR(40) ,USH        A      40
     1     ,USHI      ,USTREM               ,UW(50)   ,UWS        A      41
     2     ,X11       ,X(40)     ,X12       ,X2(40)               A      42
     3     ,XW(50)    ,XWS       ,XABAR(25) ,XBBAR(25) ,X15       A      43
     4     ,XS(25,40) ,XSH       ,XSTREM              ,XW(50)     A      44
     5     ,ZMWR(40)             ,Y11       ,Y(40)    ,Y12        A      45
     6     ,Y2(40)    ,YABAR     ,YBBAR     ,Z5(25)   ,Z11(25)    A      46
     7     ,ZJ(25,40) ,ZMW       ,S2X       ,W2SH     ,X2SH       A      47
     8     ,FX(2,40)  ,FR(2,40)  ,FPHI(2,40) ,FP(2,40) ,FT(2,40)  A      48
     9     ,FU(2,40)  ,INUL(2,40) ,INOR(2,40) ,FC(2,40,25),CANDI  A      49
     *     ,M         ,N                                          A      50
      REAL  KAY       ,KAYS(25)  ,KAY2      ,KW       ,MDOT(40)   PPTOUT   4
     *     ,MA(40)    ,MU        ,MUS(25)   ,MUO(25)  ,MU2        PPTOUT   5
     *     ,MW(25)    ,MK2       ,MASH      ,MASHI    ,MWSH       PPTOUT   6
     *,      MAP                                                  PPTOUT   7
      COMMON/PT1/XMOMV(8), XMOMP(8),ENEP1(8),REP(40,8),V(40,8),W(40,8), PPTOUT   8
     1V2(40,8), W2(40,8), TRBOY(8), TP(40,8), TP2(40,8), RP(8),     PPTOUT   9
     2RHP(40,8), RHP2(40,8) ,ENEP2(8),NBL(8),UM(40)                 PPTOUT  10


     3,VOLP(8),WIP(8),FC(8),DENG(40,8),ICOND(40,8)                  PPTOUT  11
      COMMON/PT2/FF3,FFG,GAMA,UM1,PO,NPG,KMX,DNDSP(8)               PPTOUT  12
      COMMON/PT3/CL,CS,IPS,RMSS,WT,HIRAN,SIG,EM,IPART,IKINE,IR(40)  PPTOUT  13
     1 ,SUMP,SUMPV,SUMPE                                            PPTOUT  14
      COMMON/XYZ/IXYZ,JXYZ                                          PPTOUT  15
      DIMENSION PIP(8)                                              PPTOUT  16
      IXYZ=13                                                       PPTOUT  17
      JXYZ=0                                                        PPTOUT  18
      IF(KKKK.EQ.1) GO TO 3                                         PPTOUT  19
      LKI=K-1                                                       PPTOUT  20
      LKMAX=K-1                                                     PPTOUT  21
      GO TO 4                                                       PPTOUT  22
    3 LKI=1                                                         PPTOUT  23
      LKMAX=KMX+2                                                   PPTOUT  24
    4 CONTINUE                                                      PPTOUT  25
      DO 2 LK=LKI,LKMAX                                             PPTOUT  26
      LK1=LK+1                                                      PPTOUT  27
      PIPP=0.0                                                      PPTOUT  28
      DO 6 J=1,NPG                                                  PPTOUT  29
      PIP(J)=RHP2(LK,J)*W2(LK,J)**2/(2.*BETAP)                      PPTOUT  30
      PIPP=PIPP+PIP(J)                                              PPTOUT  31
    6 CONTINUE                                                      PPTOUT  32
      WRITE(6,101) LK,S,U2(LK1),T2(LK1),RHO(LK1),RE(LK1),Y2(LK1)    PPTOUT  33
     1 ,W2(LK1)                                                     PPTOUT  34
      WRITE (6,99)                                                  PPTOUT  35
      WRITE(6,107) (J,J=1,NPG)                                      PPTOUT  36
      WRITE(6,102) (W2(LK,J),J=1,NPG)                               PPTOUT  37
      WRITE(6,103) (V2(LK,J),J=1,NPG)                               PPTOUT  38
      WRITE(6,104) (REP(LK,J),J=1,NPG)                              PPTOUT  39
      WRITE(6,105) (TP2(LK,J),J=1,NPG)                              PPTOUT  40
      WRITE(6,106) (RHP2(LK,J),J=1,NPG)                             PPTOUT  41
      WRITE(6,108) PIPP                                             PPTOUT  42
    2 CONTINUE                                                      PPTOUT  43
   99 FORMAT (1H ,39H===== PARTICLE PHASE PROPERTIES =====     )    PPTOUT  44
  101 FORMAT (1H ,15H===STREAMLINE= ,I5,4H  S=,F12.5/,2X,23H== LOCAL GAS PPTOUT  45
     1 PROPERTIES /,2X,2HU=,1PE10.3,2X,2HT=,E10.3,2X,8HDENSITY=,E10.3, PPTOUT  46
     2 2X,13HREYNOLDS NO.=,E10.3,2X,3HY2=,E10.3,2X,3HW2=,E10.3)     PPTOUT  47
  102 FORMAT (1H ,19HDOWNSTREAM VELOCITY ,2X,1P8E12.3)              PPTOUT  48
  103 FORMAT(1H ,21HCROSS-STREAM VELOCITY,1P8E12.3)                 PPTOUT  49
  104 FORMAT(1H ,21HPARTICLE REYNOLDS NO.,1P8E12.3)                 PPTOUT  50
  105 FORMAT(1H ,20HPARTICLE TEMPERATURE,1X,1P8E12.3)               PPTOUT  51
  106 FORMAT(1H ,16HPARTICLE DENSITY,5X,1P8E12.3)                   PPTOUT  52
  107 FORMAT(1H ,14HPARTICLE GROUP,8(7X,I5))                        PPTOUT  53
  108 FORMAT(1H,24H PARTICLE MOMENTUM FLUX  ,2X,1P8E12.3  )         PPTOUT  54
      RETURN                                                        PPTOUT  55
      END                                                           PPTOUT  56


      SUBROUTINE SHOCKF                                             SHOCKF   2
      RETURN                                                        SHOCKF   3
      END                                                           SHOCKF   4


      SUBROUTINE COMBO(L)                                           COMBO    2
      RETURN                                                        COMBO    3
      END                                                           COMBO    4


      SUBROUTINE STEP                                               STEP     2
C     THIS SUBROUTINE CALCULATES STATE PROPERTIES IN A STREAMTUBE   STEP     3
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      COMMON A(25,7)     ,AA(40)       ,ALFA(25,25),ALPHAM   ,ALPHAP
     1       ,ATOL        ,BETAP        ,BMIX         ,C11(25)     ,C(25,40)
     2       ,C12(25)     ,C2(25,40)    ,CABAR(25)    ,CBBAR(25)   ,CP
     3       ,CPS(25)     ,CPSH         ,CSH(25)      ,CSH1(25)    ,CSTHEM(25)
     4       ,CXSTHP      ,D2IH(25,25),DEFF(25)     ,D2EFF(25)   ,DELTA
     5       ,D11         ,DELSS(40)    ,DELS         ,DELSO       ,DLS(40)
     6       ,DIH(25,25) ,D12          ,DELY(40)     ,D13         ,DPUTE(40)
     7       ,D14         ,DPHIDS(40)   ,EPCON
     8       ,EPSLON      ,EXTRA(50)    ,FSTEP        ,FMAX        ,GRAD
     9       ,H11         ,H(40)        ,HH           ,HJ          ,HPH(25)
     0       ,H2PH(25)    ,H3PH(25)     ,ICONST       ,ICOUNT      ,IDENT(25)
     1       ,IERROR      ,IEXTRA(50)   ,IFLAG        ,IRING
     2       ,IPTOC       ,ISHOCK       ,ITYPE        ,IPH
     3       ,IDIFF       ,K            ,KAY          ,KAYS        ,KAY2
     4       ,KLO         ,KMAX
     5       ,KUP         ,KK           ,LL           ,LPLANE      ,MA
     6       ,MASH        ,MDOT         ,MMAX         ,MUO         ,MU
     7       ,MU2         ,MUS          ,MM           ,MM2         ,MBSH
     8       ,NBOUND      ,NCS          ,NITER        ,NMAX        ,NN
      COMMON NOCASE       ,OMEGA(25)    ,P11          ,P(40)       ,P12
     1       ,P2(40)                    ,PE(50)       ,PABAR       ,PBBAR
     2       ,PHS         ,P15          ,PHI(40)                   ,PHIB(50)
     3       ,PHISH1      ,PHSTHM                     ,PHIW(50)    ,P18
     4       ,PHI2(40)    ,PHIUS        ,PI           ,PW(25)      ,PSH
     5       ,PSH1        ,PSI          ,PSTHEM                    ,PW(50)
     6       ,Q11         ,Q(40)        ,QXTR1        ,QXTR2
     7       ,QA(50)      ,R11          ,R(40)                     ,RB(50)
     8       ,RHS         ,R13          ,RBAR(40)     ,R14         ,R2(40)
     9       ,RCON        ,R15          ,RE(40)       ,RESH        ,R16
     0       ,RHO(40)     ,R17          ,RHO2(40)     ,RHS(25)     ,RHSEN
     1       ,RHSNCK      ,RHABAR       ,RHBBAR       ,RU          ,RSH
     2       ,RSTHEM      ,RV           ,R19          ,RR(100)     ,S
     3                    ,SE(50)       ,SC(25)                    ,SA(50)
     4       ,S13         ,SX(40)       ,T11          ,T(40)       ,T12
     5       ,T2(40)      ,TABAR        ,TBBAR        ,TO(25)      ,T14
     6       ,TAR(40)     ,TXTR1        ,TXTR2        ,TOL         ,TSH
     7       ,TSH1        ,TSTHEM                     ,TA(50)      ,TAS
     8       ,TS          ,U11          ,U(40)        ,U12         ,U2(40)
      COMMON UXTR1        ,UXTR2        ,U14          ,UBAR(40)    ,USH
     1       ,USH1        ,USTHEM                     ,UA(50)      ,UAS
     2       ,X11         ,X(40)        ,X12          ,X2(40)
     3       ,XB(50)      ,XBS          ,XABAR(25)    ,XBBAR(25)   ,X15
     4       ,XS(25,40)   ,XSH          ,XSTHEM                    ,XA(50)
     5       ,ZMAR(40)                  ,Y11          ,Y(40)       ,Y12
     6       ,Y2(40)      ,YABAR        ,YBBAR        ,ZA(25)      ,Z11(25)
     7       ,ZJ(25,40)   ,ZHR          ,S2X          ,R2SH        ,X2SH
     8       ,FX(2,40)    ,FR(2,40)     ,FPHI(2,40)   ,FP(2,40)    ,FT(2,40)
     9       ,FU(2,40)    ,INDL(2,40)   ,INDR(2,40)   ,FC(2,40,25),CARD1
     *       ,W           ,N
      REAL    KAY         ,KAYS(25)     ,KAY2         ,KA          ,MDOT(40)
     *       ,MA(40)      ,MU           ,MUS(25)      ,MUO(25)     ,MU2
     *       ,MR(25)      ,MM2          ,MASH         ,MASH1       ,MBSH
     * ,      MAP
      COMMON/PT1/XNUMP(8), XNUMP(8),ENEP1(8),REP(40,8),V(40,8),R(40,8),
     1V2(40,8), R2(40,8), THBDY(8), TP(40,8), TP2(40,8), NP(8),
     2RBP(40,8), RBP2(40,8) ,ENEP2(8),NBL(8),UM(40)
     3,VOLF(8),AIP(8),HL(8),DENG(40,8),ICOND(40,8)
      COMMON/PT2/FFF,FFG,GAMA,OMI,PO,NPG,KPX,DNOSP(8)
      COMMON/PT3/CL,CS,TPS,RHSS,AT,HIRAN,SIG,EF,IPART,IKINE,IR(40)
     1 ,SUPP,SUPPV,SUPPE
      COMMON/IBUGS1/ IBUGSH
      COMMON/CHEM1/ ZID(5), IRR(40),INT(40),RC(40,3),IRRR(40,5),
     1 AV,CM(26,26),F1(26),RP(26),
     2 RR(26),ROUT(26,40),CSI(26),QX(26)
      COMMON/XYZ/IXYZ,JXYZ
      DIMENSION ZAU(25)
      EQUIVALENCE (IVISC,IEXTRA(1))
      EQUIVALENCE (RALAMR,IEXTRA(20))
      IXYZ=17
      JXYZ=0
C     EVALUATION OF TRANSPORT TERMS
C     FOR IVISC=1 (ITUPE=1), CALL VISCO IMMEDIATELY
C     THIS RUNS PROGRAM WITH VISCOSITY
      IF (IVISC) 50,50,200
   50 RHSMOM=0.0
      RHSENG=0.0
      DO 100 I=1,NOS
  100 RHS(I)=0.0
      IF (IFLAG) 125,150,125
  125 UBAR(K)=U2(K)
C     FOR NO VISCOSITY CALL VISCO ONLY AT BOUNDARY TO CALC BOUNDARY LAYE
      IF (FBOUND) 300,300,200
  150 UBAR(K)=U(K)
      IF (RROUGH) 300,300,200
  200 CALL VISCO
      PULT=IEXTRA(48)
      IHIG=IEXTRA(49)
      IF (K.LT.KMAX) GO TO 250
      TABAR=TABAR
      PBBAR=PABAR
      DO 225 I=1,NOS
  225 XBBAR(I)=XABAR(I)
  250 RP=ALPHAP
  300 AEL=RPI*(R(K)+R(K-1))*DELTA*(Y(K)-Y(K-1))
      ABAR=.5*(AA(K)+AA(K))
      IF(IRIPE.NE.0.AND.IFLAG.EQ.1) GO TO 401
  350 DO 400 I=1,NOS
  400 C2(I,K)=C(I,K)+RHS(I)/MDOT(K)
```

```
      GO TO 402
  401 CALL CHEM(IKINE)
  402 CONTINUE
      DO 403 I=1,NDS
      IF(C2(I,K)) 404,403,403
  403 CONTINUE
      GO TO 405
  404 DELS=DELS*.5
      ICOUNT=ICOUNT+1
      KALARM=2
      GO TO 10000
  405 ZMM=0.0
      DO 500 I=1,NDS
  500 ZMM=ZMM+C2(I,K)/W(I)

      ZMM=1.0/ZMM
      ZMW(K)=ZMM
      DO 600 J=1,NN
      ZA(J)=0.0
      ZAD(J)=0.
      DO 600 I=1,NDS
      ZAD(J)=ZAD(J)+A(I,J)*C(I,K)
  600 ZA(J)=ZA(J)+A(I,J)*C2(I,K)
      ITER=0
  700 US=UMAX(K)
      CP=0.0
      CPOLD=0.
      DO 702 J=2,NN
      CPOLD=CPOLD+FLOAT(J-2)*ZAD(J)*T(K)**(J-3)
  702 CP=CP+ZA(J)*FLOAT(J-2)*T   (K)**(J-3)
      B1=(RHSNGM+MDOT(K)*U(K))/(BETAP*ABAR)+P(K)
      B1= B1-DELS(K)*SUMP/BETAP
      B2=MDOT(K)/(BETAP*ABAR)
  706 B3=ZMM*AA(K)/RV/MDOT(K)
      IF (IBUGSH.EQ.0) GO TO 703
      WRITE (6,2001) ACLD,B1,B2,B3
 2001 FORMAT (1H0,5HACLD=,1PE11.4,5H  B1=,1PE11.4,5H  B2=,1PE11.4,5H
     * B3=,1PE11.4,6E10.3)
  703 IF (MA(K)-1.002) 1400,1400,704
  704 IF (ICONST)  705,710,705
  705 IF(MA(K)-5.0) 800,710,710
C     CONSTANT GAMMA
  710 B5=HJ*CP*B3*B1
      B6=2.0*HJ*CP*B3*B2-1.0
      B4=U(K)**2+2.0*HJ*(RHSEN/MDOT(K)+CPOLD*T(K)+ZAD(2)-ZA(2))
      B4=B4+SUMPE*ABAR*DLS(K)/MDOT(K)
      DISCR=B5**2-B6*B4
      IF (IBUGSH.NE.0) WRITE (6,2001) B4,B5,B6,DISCR
     1  ,SUMPE,ZA(1),ZAD(1),T(K),RHSEN
      IF (DISCR) 730,750,750
  730 IF (ICOUNT-9) 740,740,9800
  740 ICOUNT=ICOUNT+1
      DELS=DELS/2.0
      KALARM=2
      GO TO 10000
  750 US=(B5+SQRT(DISCR))/B6
      IF (IBUGSH.NE.0) WRITE (6,2001) US,T(K),P(K),U(K)
      GO TO 1200
C     VARIABLE HEAT CAPACITY
  800 ITER=ITER+1
      B4=2.0*HJ*RHSEN/MDOT(K)+2.0*HJ*H(K)+U(K)**2
      B4=B4+SUMPE*ABAR*DLS(K)/MDOT(K)
      DUM1=0.0
      DUM2=0.0
      DO 900 I=1,NN
      DUM1=DUM1+ZA(I)*(B3*(B1-B2*US)*US)**(I-2)
  900 DUM2=DUM2+ZA(I)*FLOAT(I-2)*   (B1*US-B2*US**2) **(I-3)*B3**(I-2)
      G=2.0*HJ*DUM1+US**2-B4
      DGDU=2.0*US+2.0*HJ*DUM2*(B1-2.0*B2*US)
      DELTAU=-G/DGDU
      IF (ABS(DELTAU/US)-TOL) 1200,1000,1000
 1000 IF (ITER-NITER) 1100,1010,1010

 1010 IF (ICOUNT-9) 1020,1020,9500
 1020 ICOUNT=ICOUNT+1
      KALARM=2
      DELS=DELS/2.0
      GO TO 10000
 1100 US=US+DELTAU
      GO TO 800
 1200 U2(K)=US
      P2(K)=B1-B2*US
      T2(K)=B3*P2(K)*US
 1300 RHO2(K)=ZMM*P2(K)/(RV*T2(K))
      IF (P2(K)) 1301,1301,1304
 1301 IF (ICOUNT.LT.9) GO TO 1020
      WRITE (6,1302)
 1302 FORMAT(26H1 PRESSURE BECAME NEGATIVE)
 1303 CALL POUMP(A(1,1),N,1)
      CALL EXIT
 1304 IF (T2(K)) 1305,1305,1307
 1305 IF (ICOUNT.LT.9) GO TO 1020
      WRITE (6,1306)
 1306 FORMAT(29H1 TEMPERATURE BECAME NEGATIVE)
      GO TO 1303
C     STAGNATION MACH AND REYNOLDS NUMBERS
 1307 F=AX=1.0
      IF (K.NE.KMAX) GO TO 1309
      NO2=N1
      KAY2=KAY
      DO 1308 I=1,NES
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      D2EFF(I)=DEFF(I)                                                  STEP     153
      DO 1308 J=1,NOS                                                   STEP     154
      D2IN(I,J)=DIN(I,J)                                                STEP     155
 1308 CONTINUE                                                          STEP     156
 1309 CP=0.                                                             STEP     157
      DO 1310 I=1,NN                                                    STEP     158
 1310 CP=CP+FLOAT(I-2)*ZA(I)*T2(K)**(I-3)                               STEP     159
      IF (IVISC) 1315,1360,1315                                         STEP     160
 1315 IF (KAY2-MU2*CP) 1330,1330,1320                                   STEP     161
 1320 FMAX=KAY2/(CP*MU2)                                                STEP     162
 1330 IF (MULT.NE.0.AND.AS(IHIG,K+1).GT.0.75) GO TO 1352                STEP     163
      JMAX=NOS-1                                                        STEP     164
      DO 1350 I=1,JMAX                                                  STEP     165
      J=I                                                               STEP     166
 1335 J=J+1                                                             STEP     167
      IF (D2IN(I,J)*RHO2(K)/MU2-FMAX) 1345,1345,1340                    STEP     168
 1340 IF (MULT.NE.0.AND.AS(IHIG,K+1).GT.0.75) GO TO 1342                STEP     169
      FMAX=D2IN(I,J)*RHO2(K)/MU2                                        STEP     170
      GO TO 1345                                                        STEP     171
 1342 FMAX=D2EFF(J)*RHO2(K)/MU2                                         STEP     172
 1345 IF (J.LT.NOS) GO TO 1335                                          STEP     173
 1350 CONTINUE                                                          STEP     174
      GO TO 1355                                                        STEP     175
 1352 DO 1353 I=1,NOS                                                   STEP     176
      IF (D2EFF(I)*RHO2(K)/MU2.GT.FMAX) FMAX=D2EFF(I)*RHO2(K)/MU2       STEP     177
 1353 CONTINUE                                                          STEP     178
 1355 IF (IHUGSH.NE.0) WRITE (6,1375) RHO2(K),U2(K),DELY(K),MU2,KAY2,FMA STEP     179
     1X,CP                                                              STEP     180
 1375 FORMAT (6H RHO2=,E11.4,5H  U2=,E11.4,7H  DELY=,E11.4/5H MU2=,E11.4 STEP     181


     1,7H  KAY2=,E11.4,7H  FMAX=,E11.4,5H  CP=,E11.4)                   STEP     182
      RE(K)=RHO2(K)*U2(K)*DELY(K)/(MU2*FMAX)                            STEP     183
      IF (IHUGSH.NE.0) WRITE (6,1358) RE(K)                             STEP     184
 1358 FORMAT (4H RE=,E11.4)                                             STEP     185
 1360 MA(K)=U2(K)/SQRT((CP*ZMA-RCON)/(CP*T2(K)*RU))                     STEP     186
      GAMA=CP/(CP-RCON/ZMA )                                            STEP     187
      MU= 4.0*GAMA/(9.*GAMA-5.0)                                        STEP     188
      GO TO 10000                                                       STEP     189
 1400 CONTINUE                                                          STEP     190
C     ERROR MESSAGES                                                    STEP     191
 9300 NUCASE=2250                                                       STEP     192
      GO TO 9900                                                        STEP     193
 9400 NUCASE=730                                                        STEP     194
      WRITE (6,8888) NUCASE                                             STEP     195
      GO TO 9900                                                        STEP     196
 9500 NUCASE=1010                                                       STEP     197
      WRITE (6,8888) NUCASE                                             STEP     198
 8888 FORMAT (1H1,15X,* ------------- NUCASE=*,I5//)                    STEP     199
 9900 IERROR=3                                                          STEP     200
10000 RETURN                                                            STEP     201
      END                                                               STEP     202

      FUNCTION  ERF(X)                                                  ERF        2
C     ----- THIS CALCULATES THE ERROR FUNCTION AND ITS COMPLEMENT -----  ERF        3
      DATA EPSILN/1.0E-10/,N/100/,CONST/1.1283791670955/                ERF        4
      NOMPLE=1                                                          ERF        5
      GO TO 5                                                           ERF        6
      ENTRY ERFC                                                        ERF        7
      NOMPLE=-1                                                         ERF        8
    5 IF (X) 10,55,15                                                   ERF        9
   10 Z=-X                                                              ERF       10
      GO TO 20                                                          ERF       11
   15 Z= X                                                              ERF       12
   20 IF (Z-5.) 25,25,45                                                ERF       13
   25 ZSQ=Z*Z                                                           ERF       14
      TERM=CONST*Z*EXP(-ZSQ)                                            ERF       15
      ERF=TERM                                                          ERF       16
      I=0                                                               ERF       17
      F=1.0                                                             ERF       18
   30 I=I+1                                                             ERF       19
      F=F+2.0                                                           ERF       20
      TERM=2.0*ZSQ*TERM/F                                               ERF       21
      ERF=ERF+TERM                                                      ERF       22
      IF (I-N) 35,40,40                                                 ERF       23
   35 IF (TERM-EPSILN*ERF) 40,30,30                                     ERF       24
   40 IF (ERF-1.0) 50,50,45                                             ERF       25
   45 ERF=1.0                                                           ERF       26
   50 IF (X) 60,55,65                                                   ERF       27
   55 ERF=0.0                                                           ERF       28
      GO TO 65                                                          ERF       29
   60 ERF=-ERF                                                          ERF       30
   65 IF (NOMPLE) 70,99,99                                              ERF       31
C     ----- COMPUTE COMPLEMENTARY ERROR FUNCTION ERF -----              ERF       32
   70 ERF=1.0-ERF                                                       ERF       33
   99 RETURN                                                            ERF       34
      END                                                               ERF       35


      SUBROUTINE TRANSP (TT,PP,KKK,MULT,IHIG)                           TRANSP     2
C     -- THIS SUBROUTINE CALCULATES THE TURBULENT TRANSPORT PROPERTIES - TRANSP     3
      COMMON A(25,7)     ,AA(40)     ,ALFA(25,25),ALPHAM     ,ALPHAP     A          2
     1       ,ATOM       ,BETAP      ,BMIX       ,C1(25)     ,C(25,40)   A          3
     2       ,C12(25)    ,C2(25,40)  ,CAMAR(25)  ,CMMAR(25)  ,CP         A          4
     3       ,CPS(25)    ,CPSM       ,CSM(25)    ,CSM1(25)   ,CSIMPP(25) A          5
     4       ,DASIM      ,D2IN(25,25),DEFF(25)   ,D2EFF(25)  ,DELTA      A          6
     5       ,D1         ,DELSS(40)  ,DELS       ,DELSM      ,DLS(40)    A          7
     6       ,DIN(25,25) ,D12        ,DELY(40)   ,D11        ,DPDT(40)   A          8
     7       ,E,9        ,EPMIOS(40) ,EP(6)                              A          9
     8       ,EPLCES     ,EXTRA(50)  ,FSTEP      ,FMAX       ,GRAD       A         10
     9       ,H11        ,H(40)      ,HH         ,HJ         ,HP(25)     A         11
     A       ,H2(25)     ,HSP(25)    ,ICCNST     ,ICOUNT     ,IDEST(25)  A         12
```

```
     1       ,IERROR      ,IEXTRA(50) ,IFLAG      ,IKIND                  A        13
     2       ,IPTUC       ,ISHOCK     ,ITYPE      ,IPO                    A        14
     3       ,IDIFF       ,K          ,KAY        ,KAYS       ,KAY2       A        15
     4       ,KLU         ,KMAX                                           A        16
     5       ,KUP         ,KW         ,LL         ,LPLANE     ,MA         A        17
     6       ,MASH        ,MDOT       ,MMAX       ,MUO        ,MU         A        18
     7       ,MU2         ,MUS        ,MW         ,MW2        ,MASH       A        19
     8       ,NBOUND      ,NUS        ,NITER      ,NMAX       ,NN         A        20
     COMMON NOCASE      ,OMEGA(25)  ,P11        ,P(40)      ,P12        A        21
     1       ,P2(40)                  ,PB(50)     ,PAHAR      ,PBHAR      A        22
     2       ,PFS         ,P15        ,PHI(40)                ,PHIW(50)   A        23
     3       ,PHISH1      ,PHSTRM                 ,PHIW(50)   ,P18        A        24
     4       ,PHI2(40)    ,PHIBS      ,PI         ,PR(25)     ,PSH        A        25
     5       ,PSH1        ,PS1        ,PSTREM                 ,PW(50)     A        26
     6       ,Q11         ,Q(40)      ,QXTR1      ,QXTR2                  A        27
     7       ,QW(50)      ,R11        ,R(40)                  ,RB(50)     A        28
     8       ,RHS         ,R13        ,RBAR(40)   ,R14        ,R2(40)     A        29
     9       ,RCUR        ,R15        ,RE(40)     ,RESH       ,R16        A        30
     *       ,RHO(40)     ,R17        ,RHO2(40)   ,RHS(25)    ,RHSEN      A        31
     1       ,RHSROM      ,RHAHAR     ,RHBBAR     ,RU         ,RSH        A        32
     2       ,RSTREM      ,RV         ,R19        ,RW(100)    ,S          A        33
     3                    ,SB(50)     ,SL(25)                 ,SW(50)     A        34
     4       ,S13         ,SX(40)     ,T11        ,T(40)      ,T12        A        35
     5       ,T2(40)      ,TAHAR      ,TBBAR      ,TO(25)     ,T14        A        36
     6       ,TAN(40)     ,TXTR1      ,TXTR2      ,TOL        ,TSH        A        37
     7       ,TSH1        ,TSTREM                 ,TW(50)     ,TWS        A        38
     8       ,TS          ,U11        ,U(40)      ,U12        ,U2(40)     A        39
     COMMON UXTR1       ,UXTR2      ,U14        ,UBAR(40)   ,USH        A        40
     1       ,USH1        ,USTREM                 ,UW(50)     ,UWS        A        41
     2       ,X11         ,X(40)      ,X12        ,X2(40)                 A        42
     3       ,XB(50)      ,XB2        ,XAHAR(25)  ,XBBAR(25)  ,X15        A        43
     4       ,XS(25,40)   ,XSH        ,XSTREM                 ,XW(50)     A        44
     5       ,ZMAR(40)                ,Y11        ,Y(40)      ,Y12        A        45
     6       ,Y2(40)      ,YAHAR      ,YBBAR      ,ZA(25)     ,Z11(25)    A        46
     7       ,ZJ(25,40)   ,ZMA        ,S2X        ,R2SH       ,X2SH       A        47
     8       ,FX(2,40)    ,FR(2,40)   ,FPHI(2,40) ,FP(2,40)   ,FT(2,40)   A        48
     9       ,FU(2,40)    ,INDL(2,40) ,INDR(2,40) ,FC(2,40,25),CARD1      A        49
     *       ,M           ,N                                              A        50
      REAL    KAY         ,KAYS(25)   ,KAY2       ,KW         ,MDOT(40)   TRANSP    5
     *       ,MA(40)      ,MU         ,MUS(25)    ,MUO(25)    ,MU2        TRANSP    6
     *       ,MW(25)      ,MW2        ,MASH       ,MASH1      ,MASH       TRANSP    7
     * ,          KAP                                                     TRANSP    8
      COMMON/RHELE/RHEE(40)                                               TRANSP    9
      COMMON/TURBUL/TLE,TPR,EDDYK,ITURB,DELMIX                            TRANSP   10


      COMMON/INPUX/ITI,X0,Y0,FRAC  ,KFL                                   TRANSP   11
      COMMON/XYZ/IXYZ,JXYZ                                                TRANSP   12
      COMMON/PERGFF/PERGF                                                 TRANSP   13
      IXYZ=18                                                             TRANSP   14
      JXYZ=0                                                              TRANSP   15
      KAY2=KAY                                                            TRANSP   16
      MU2=MU                                                              TRANSP   17
      D2IM(1,2)=DIM(1,2)                                                  TRANSP   18
      IF (IHUGSH.NE.0)                                                    TRANSP   19
     1 WRITE(6,700) KKK,LL,MDOT(KKK),U(KKK),RHO(KKK),RHO(KKK+1),IFLAG     TRANSP   20
      IF (KKK-2) 100,100,450                                              TRANSP   21
  100 IF (LL .LT. 0) GO TO 400                                            TRANSP   22
      IF (ITURB -2) 301,302,400                                           TRANSP   23
  302 RUMAX=RHO(2)*U(2)                                                   TRANSP   24
      RUMIN=RHO(2)*U(2)                                                   TRANSP   25
      DO 300 L=2,KMAX                                                     TRANSP   26
      TEST = RHO(L)*U(L)                                                  TRANSP   27
      IF (TEST .GT. RUMAX) GO TO 200                                      TRANSP   28
      IF (TEST .GE. RUMIN) GO TO 300                                      TRANSP   29
      RUMIN = TEST                                                        TRANSP   30
      GO TO  300                                                          TRANSP   31
  200 RUMAX=TEST                                                          TRANSP   32
  300 CONTINUE                                                            TRANSP   33
      DELMIX=Y(KMAX)                                                      TRANSP   34
      MU=          (DELMIX/EDDYK)*(RUMAX-RUMIN)     *.007696              TRANSP   35
      WRITE(6,11) RUMAX,RUMIN,DELMIX,MU,RHO(KMAX),U(KMAX),RHAHAR          TRANSP   36
      GO TO 450                                                           TRANSP   37
  301 KMM=KMAX-1                                                          TRANSP   38
C     ***** DETERMINE DIVIDING STREAMLINE *****                           TRANSP   39
      TAMM=TAN(2)                                                         TRANSP   40
      KDSL=2                                                              TRANSP   41
      DO 800 IF=2,KMM                                                     TRANSP   42
      IF (ABS(TAN(IF+1)).LE.ABS(TAMM)) GO TO 800                          TRANSP   43
      KDSL=IF+1                                                           TRANSP   44
      TAMM=TAN(KDSL)                                                      TRANSP   45
  800 CONTINUE                                                            TRANSP   46
      RIN=R(KDSL)                                                         TRANSP   47
C     ***** COMPUTE DELMIX AND MU *****                                   TRANSP   48
      PERG=PERGF*ABS(TAMM)                                                TRANSP   49
      INN=2                                                               TRANSP   50
      DO 810 IF=3,KDSL                                                    TRANSP   51
      IF (ABS(TAN(IF)).LT.PERG) INN=IF                                    TRANSP   52
  810 CONTINUE                                                            TRANSP   53
      RINN=R(INN)                                                         TRANSP   54
      DELMIX=RDV-RINN                                                     TRANSP   55
      MU=0.5*DELMIX*RHO(KKK)*ABS(U(1)-U(KMAX))/EDDYK                      TRANSP   56
      IF (DELMIX.EQ.0.0)  MU=1.0E-5                                       TRANSP   57
      WRITE(6,10) KDSL,INN,MU,DELMIX                                      TRANSP   58
   10 FORMAT (1H ,10X,26HDIVIDING STREAMLINE=I3,5X,15HINNER BOUND SL=,    TRANSP   59
     *  I3,/X,5HMU=,1PE10.3,5X,7HDELMIX=,E10.3)                           TRANSP   60
      GO TO 450                                                           TRANSP   61
  400 MU=EDYK                                                             2SSFP1   17
  450 CP=1.0                                                              TRANSP   63
      DO 460 I=1,NCS                                                      TRANSP   64
      CPS(I)=0.0                                                          TRANSP   65
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      DO 500 J=1,NN                                                     TRANSP    66
  500 CPS(I)=CPS(I)+FLOAT(J-2)*A(I,J)*TT**(J-3)                         TRANSP    67


      IF (LL .LT. 0) GO TO 550                                          TRANSP    68
      CP=CP+CPS(I)*CABAR(I)                                             TRANSP    69
      GO TO 600                                                         TRANSP    70
  550 CP=CP+CPS(I)*C(I,KKK)                                             TRANSP    71
  600 CONTINUE                                                          TRANSP    72
      KAY=CP*MU/TPR                                                     TRANSP    73
      IF (IBUGSH.NE.0)                                                  TRANSP    74
     1WRITE(6,702) CP,KAY,RHABAR                                        TRANSP    75
      IF (LL .LT. 0) GO TO 650                                          TRANSP    76
      DIM(1,2)=KAY*TLE/(RHABAR*CP)                                      TRANSP    77
      GO TO 10000                                                       TRANSP    78
  650 DIM(1,2)=KAY*TLE/(RHO(KKK)*CP)                                    TRANSP    79
   11 FORMAT(1H ,6HPUMAX=,1PE9.2,2X,6HPUMIN=,E9.2,2X,7HDELMIX=,E9.2,2X  TRANSP    80
     1 ,3HMU=,E9.2,2X,4HRHO=,E9.2,2X,2HU=,E9.2,2X,7HRHMABAR=,E9.2)       TRANSP    81
  700 FORMAT(1H ,4HKKK=,I3,2X,3HLL=,I3,2X,5HMDOT=,1PE9.2,2X,2HU=,E9.2,   TRANSP    82
     * 2X,7HRHO(K)=,E9.2,2X,9HRHO(K+1)=,E9.2,2X,6HIFLAG=,I2)            TRANSP    83
  702 FORMAT(1H ,3HCP=,1PE9.2,2X,4HKAY=,E9.2,2X,7HRHABAR=,E9.2)         TRANSP    84
10000 RETURN                                                            TRANSP    85
      END                                                               TRANSP    86


      SUBROUTINE VISCO                                                  VISCO      2
C     THIS SUBROUTINE CALCULATES THE FLUX CONTRIBUTIONS TO THE          VISCO      3
C     CONSERVATION EQUATIONS                                            VISCO      4
      COMMON A(25,7)      ,AA(40)      ,ALFA(25,25),ALPHAH     ,ALPHAP  A          2
     1        ,ATOL       ,BETAP       ,BMIX       ,C11(25)    ,C(25,40) A          3
     2        ,C12(25)    ,C2(25,40)   ,CABAR(25)  ,CBBAR(25)  ,CP      A          4
     3        ,CPS(25)    ,CPSH        ,CSH(25)    ,CSH1(25)   ,CSTREM(25) A        5
     4        ,MXSTRM     ,D2IM(25,25),DEFF(25)   ,D2EFF(25)  ,DELTA    A          6
     5        ,D11        ,DELSS(40)   ,DELS       ,DELSO      ,DLS(40)  A          7
     6        ,DIM(25,25) ,D12         ,DELY(40)   ,D13        ,DPDY(40) A          8
     7        ,D14        ,EPHIDS(40)  ,EPCON                           A          9
     8        ,EPSLON     ,EXTRA(50)   ,FSTEP      ,FMAX       ,GRAD    A         10
     9        ,H11        ,H(40)       ,HH         ,HJ         ,HPM(25) A         11
     *        ,H2PM(25)   ,H3PM(25)    ,ICONST     ,ICOUNT     ,IDENT(25) A       12
     1        ,IERROR     ,IEXTRA(50)  ,IFLAG      ,IKIND               A         13
     2        ,IPTUC      ,ISHOCK      ,ITYPE      ,IPD                 A         14
     3        ,IDIFF      ,K           ,KAY        ,KAYS       ,KAY2    A         15
     4        ,KLO        ,KMAX                                         A         16
     5        ,KUP        ,KA          ,LL         ,LPLANE     ,MA      A         17
     6        ,MASH       ,MDOT        ,MMAX       ,MUO        ,MU      A         18
     7        ,MU2        ,MUS         ,MM         ,MM2        ,MASH    A         19
     8        ,NBOUND     ,NDS         ,NITER      ,NMAX       ,NN      A         20
      COMMON NUCASE       ,OMEGA(25)   ,P11        ,P(40)      ,P12     A         21
     1        ,P2(40)                  ,PB(50)     ,PABAR      ,PBBAR   A         22
     2        ,PHS        ,P15         ,PHI(40)                ,PHIH(50) A        23
     3        ,PHISH1     ,PHSTRM                  ,PHIW(50)   ,P18     A         24
     4        ,PHI2(40)   ,PHIRS       ,PI         ,PM(25)     ,PSH     A         25
     5        ,PSH1       ,PSI         ,PSTREM                 ,PW(50)  A         26
     6        ,Q11        ,Q(40)       ,QXTR1      ,QXTR2               A         27
     7        ,QW(50)     ,R11         ,R(40)                  ,RB(50)  A         28
     8        ,RHS        ,R13         ,RBAR(40)   ,R14        ,R2(40)  A         29
     9        ,RCON       ,R15         ,RE(40)     ,RESH       ,R16     A         30
     *        ,RHO(40)    ,R17         ,RHO2(40)   ,RHS(25)    ,RHSEN   A         31
     1        ,RHSMUM     ,RHABAR      ,RHBBAR     ,RU         ,RSH     A         32
     2        ,RSTREM     ,RV          ,R19        ,RW(100)    ,S       A         33
     3                    ,SH(50)      ,SC(25)                 ,SW(50)  A         34
     4        ,S15        ,SX(40)      ,T11        ,T(40)      ,T12     A         35
     5        ,T2(40)     ,TABAR       ,TBBAR      ,T0(25)     ,T14     A         36
     6        ,TAF(40)    ,TXTR1       ,TXTR2      ,TOL        ,TSH     A         37
     7        ,TSH1       ,TSTREM                  ,TW(50)     ,TWS     A         38
     8        ,TS         ,U11         ,U(40)      ,U12        ,U2(40)  A         39
      COMMON UXTR1        ,UXTR2       ,U14        ,UBAR(40)   ,USH     A         40
     1        ,USH1       ,USTREM                  ,UW(50)     ,UWS     A         41
     2        ,X11        ,X(40)       ,X12        ,X2(40)              A         42
     3        ,XH(50)     ,XHS         ,XABAR(25)  ,XBBAR(25)  ,X15     A         43
     4        ,XS(25,40)  ,XSH         ,XSTREM                 ,XW(50)  A         44
     5        ,ZMAR(40)                ,Y11        ,Y(40)      ,Y12     A         45
     6        ,Y2(40)     ,YABAR       ,YBBAR      ,ZA(25)     ,Z11(25) A         46
     7        ,Z2(25,40)  ,ZKA         ,S2X        ,R2SH       ,X2SH    A         47
     8        ,FX(2,40)   ,FN(2,40)    ,FPHI(2,40) ,FP(2,40)   ,FT(2,40) A        48
     9        ,FU(2,40)   ,INDL(2,40)  ,INDR(2,40) ,FC(2,40,25),CANDI   A         49
     *        ,N          ,N                                            A         50
      REAL     KAY        ,KAYS(25)    ,KAY2       ,KM         ,MDOT(40) VISCO     6
     *        ,MA(40)     ,MU          ,MUS(25)    ,MUU(25)    ,MU2     VISCO      7
     *        ,MW(25)     ,MM2         ,MASH       ,MASH1      ,MWSH    VISCO      8
     * ,       KAP                                                      VISCO      9
      COMMON /RHEFF/RHEF(40)                                            VISCO     10


      COMMON/IBUGS1/ IBUGSH                                             VISCO     11
      COMMON/XYZ/IXYZ,JXYZ                                              VISCO     12
      IXYZ=19                                                           VISCO     13
      JXYZ=0                                                            VISCO     14
      IF (P(K)) 100,400,400                                             VISCO     15
  100 WRITE (6,150)                                                     VISCO     16
  150 FORMAT(20HINEGATIVE PRESSURE IN VISCO. )                          VISCO     17
      CALL FDUMP(A(1,1),N,1)                                            VISCO     18
  400 CALL FLUX                                                         VISCO     19
  500 IF (IFLAG) 600,700,600                                            VISCO     20
  600 RBAR(K)=.5*(R(K)+R2(K))                                           VISCO     21
      GO TO 800                                                         VISCO     22
  700 RBAR(K)=R(K)                                                      VISCO     23
  800 IF (RBAR(K-1)) 900,1000,900                                       VISCO     24
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```
  900 DUMM=RBAR(K-1)**DELTA
      GO TO 1200
 1000 IF (DELTA) 900,1100,900
 1100 DUMM=1.0
C     MOMENTUM TRANSFER
 1200 RHSMOM=(RBAR(K)**DELTA*TAN(K)*DLS(K)-DUMM*TAN(K-1)*DLS(K-1))
     **PI*2.0**DELTA
C     KINETIC ENERGY TRANSFER
      IF (K-2) 1300,1300,1400
 1300 DSSPIN=RBAR(K)**DELTA*TAN(K)*(UBAR(K)+UBAR(K+1))/2.0*DLS(K)-DUMM*
     *AZ(K)*UPS*DLS(K-1)
      GO TO 1500
 1400 DSSPIN=RBAR(K)**DELTA*TAN(K)*(UBAR(K)+UBAR(K+1))/2.0*DLS(K)-DUMM*
     *AN(K-1)*(UBAR(K)+UBAR(K-1))/2.0*DLS(K-1)
C     ENERGY TRANSFER BY DIFFUSION
 1500 DFFLX=0.0
      DO 1700 I=1,NDS
      H3PM(I)=H2PM(I)
      H2PM(I)=HPM(I)
      HPM(I)=0.0
      IF(K+1-KMAX)1550,1650,1650
 1550 IF (IFLAG) 1570,1560,1570
 1560 HPM(I)=CPS(I)*T(K+1)
      GO TO 1650
 1570 HPM(I)=CPS(I)*.5*(T(K+1)+T2(K+1))
 1650 DFFLX=DFFLX+.5*RBAR(K)**DELTA*ZJ(I,K)*DLS(K)*(HPM(I)+H2PM(I))
     *-.5*DUMM*ZJ(I,K-1)*DLS(K-1)*(H2PM(I)+H3PM(I))
C   SPECIES TRANSFER
 1700 RHS(I)=(RBAR(K)**DELTA*ZJ(I,K)*DLS(K)-DUMM*ZJ(I,K-1)*DLS(K-1))*PI
     **2.0**DELTA
C   TOTAL ENERGY TRANSFER
      RHSEN=(DFFLX+DSSPIN/HJ+RBAR(K)**DELTA*Q(K)*DLS(K)-DUMM*Q(K-1)*DLS(
     *K-1))*PI*2.0**DELTA
      RHEE(K)=ABS(RHSMOM)+RHEE(K)
      IF (IBUGSH.EQ.0) GO TO 10000
      WRITE (6,2001)
 2001 FORMAT (1H0,7HRHSSUM))
      DO 2100 I=1,NDS
      WRITE (6,2002) RHS(I)
 2100 CONTINUE
 2002 FORMAT (3X,1P1E11.4)
      WRITE (6,2003) RHSMOM,DFFLX,DSSPIN,RHSEN
 2003 FORMAT (1H0,7HRHSMOM=,1P1E11.4,8H  DFFLX=,1P1E11.4,9H  DSSPIN=,1P1
     *E11.4,8H  RHSEN=,1P1E11.4)
10000 RETURN
      END
      SUBROUTINE SLOP(X,A,N)
C     THIS PROGRAM FINDS THE SOLUTIONS TO A SET OF N SIMULTANEOUS LINEAR
C     EQUATIONS BY USING THE GAUSS-JORDAN REDUCTION ALGORITHM WITH THE
C      DIAGONAL PIVOT STRATEGY
      DIMENSION A(26,26),X(26)
      DO 9 K=1,N
      IF (ABS(A(K,K)) .GT. 1.E-10) GO TO 5
      WRITE (6,101)   K,A(K,K)
      DO 10 IR=1,N
      WRITE(6,100)(A(IR,JR),JR=1,N),X(IR)
   10 CONTINUE
  100 FORMAT(1X,      10F12.3)
  101 FORMAT(22H ERROR--- SMALL PIVOT  ,I5,  E12.5)
      STOP
    5 KP1= K+1
      DO 6 J= KP1, N
    6 A(K,J)= A(K,J)/A(K,K)
      X(K)= X(K)/A(K,K)
      A(K,K)= 1.0
      DO 9 I=1,N
      IF (I.EQ.K .OR. A(I,K).EQ.0.) GO TO 9
      DO 8 J=KP1,N
    8 A(I,J)= A(I,J)- A(I,K)*A(K,J)
      X(I)= X(I)- A(I,K)*X(K)
      A(I,K)=0.
    9 CONTINUE
   99 CONTINUE
      RETURN
      END

      SUBROUTINE MODEL
      COMMON A(25,7)       ,AA(40)       ,ALFA(25,25),ALPHAM      ,ALPHAP
     1       ,ATOL         ,BETAP        ,BMIX        ,C11(25)     ,C(25,40)
     2       ,C12(25)      ,C2(25,40)    ,CABAR(25)   ,COBAR(25)   ,CP
     3       ,CPS(25)      ,CPSH         ,CSH(25)     ,CSH1(25)    ,CSTREM(25)
     4       ,DXSTEP       ,D2IN(25,25)  ,DEFF(25)    ,D2EFF(25)   ,DELTA
     5       ,D11          ,DELSS(40)    ,DELS        ,DELSO       ,DLS(40)
     6       ,DIM(25,25)   ,D12          ,DELY(40)    ,D13         ,DPDY(40)
     7       ,D14          ,DPHIDS(40)   ,EPCON
     8       ,EPSLON       ,EXTRA(50)    ,FSTEP       ,FMAX        ,GRAD
     9       ,H11          ,H(40)        ,HH          ,HJ          ,HPM(25)
     *       ,H2PM(25)     ,H3PM(25)     ,ICONST      ,ICOUNT      ,IDENT(25)
     1       ,IERROR       ,IEXTRA(50)   ,IFLAG       ,IKIND
     2       ,IPTOC        ,ISHOCK       ,ITYPE       ,IPO
     3       ,IDIFF        ,K            ,KAY         ,KAYS        ,KAY2
     4       ,KLO          ,KMAX
     5       ,KOP          ,KP           ,LL          ,LPLACE      ,MA
     6       ,MASH         ,MCOT         ,MMAX        ,MOG         ,MU
     7       ,MUZ          ,MUS          ,MN          ,MY2         ,MASH
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      8       ,NBOUND     ,NDS        ,NITER      ,NMAX       ,NN          A        20
       COMMON NUCASE      ,OMEGA(25)  ,P11        ,P(40)      ,P12         A        21
      1       ,P2(40)                 ,PB(50)     ,PABAR      ,PBBAR       A        22
      2       ,PBS        ,P15        ,PHI(40)                ,PHIB(50)    A        23
      3       ,PHISH1     ,PHSTRM                 ,PHIW(50)   ,P1W         A        24
      4       ,PH12(40)   ,PHIHS      ,PI         ,PR(25)     ,PSH         A        25
      5       ,PSH1       ,PSI        ,PSTREM                 ,PW(50)      A        26
      6       ,U11        ,Q(40)      ,QXTR1      ,QXTR2                   A        27
      7       ,QW(50)     ,R11        ,R(40)                  ,RB(50)      A        28
      8       ,RBS        ,R13        ,RBAR(40)   ,R14        ,R2(40)      A        29
      9       ,RCON       ,R15        ,RE(40)     ,RESH       ,R16         A        30
      *       ,RHO(40)    ,R17        ,RHO2(40)   ,RHS(25)    ,RHSEN       A        31
      1       ,RHSHOM     ,RHABAR     ,RHBBAR     ,RU         ,RSH         A        32
      2       ,RSTREM     ,RV         ,R19        ,RW(100)    ,S           A        33
      3                   ,SB(50)     ,SC(25)                 ,SW(50)      A        34
      4       ,S13        ,SX(40)     ,T11        ,T(40)      ,T12         A        35
      5       ,T2(40)     ,TABAR      ,TBBAR      ,TO(25)     ,T14         A        36
      6       ,TAA(40)    ,TXTR1      ,TXTR2      ,TOL        ,TSH         A        37
      7       ,TSH1       ,TSTREM                 ,TW(50)     ,TW3         A        38
      8       ,TS         ,U11        ,U(40)      ,U12        ,U2(40)      A        39
       COMMON UXTR1       ,UXTR2      ,U14        ,UBAR(40)   ,USH         A        40
      1       ,USH1       ,USTREM                 ,UW(50)     ,UWS         A        41
      2       ,X11        ,X(40)      ,X12        ,X2(40)                  A        42
      3       ,XB(50)     ,XBS        ,XABAR(25)  ,XBBAR(25)  ,X15         A        43
      4       ,XS(25,40)  ,XSH        ,XSTREM                 ,XW(50)      A        44
      5       ,ZMAR(40)               ,Y11        ,Y(40)      ,Y12         A        45
      6       ,Y2(40)     ,YABAR      ,YBBAR      ,ZA(25)     ,Z11(25)     A        46
      7       ,ZJ(25,40)  ,ZMW        ,S2X        ,R2SH       ,X2SH        A        47
      8       ,FX(2,40)   ,FR(2,40)   ,FPHI(2,40) ,FP(2,40)   ,FT(2,40)    A        48
      9       ,FU(2,40)   ,INDL(2,40) ,INDR(2,40) ,FC(2,40,25),CAR01       A        49
      *       ,M          ,N                                               A        50
       COMMON/WALL/ TWALL                                              BOUNDL        4
       COMMON/BLOUT/ REXI,THETAI,CFI,UFI,CFCCFI,M12,DISP,THETAC(2),DELTI, BOUNDL     5
      *DELTAC,CFC,QWALL,TAUWAL,ETA(140),TETC(140),UBUFI(140),YDELI(140)  BOUNDL      6
       DIMENSION U1INT(140),U2INT(140)                                 BOUNDL        7
       REAL   KAY         ,KAYS(25)   ,KAY2       ,KW         ,MDOT(40),   BOUNDL    8
      *       ,MA(40)     ,MU         ,MUS(25)    ,MU0(25)    ,MU2         BOUNDL    9
      *       ,MW(25)     ,MW2        ,MASH       ,MASH1      ,MWSH        BOUNDL   10


      *,      WAP                                                      BOUNDL       11
       REAL MUEREF                                                     BOUNDL       12
       IF (LL) 90,90,91                                                BOUNDL       13
   90  QWALL=0.0                                                       BOUNDL       14
       TAUWAL=0.0                                                      BOUNDL       15
       GO TO 500                                                       BOUNDL       16
   91  CONTINUE                                                        BOUNDL       17
       MUEREF=491.E-06                                                 BOUNDL       18
       TE=T2(KMAX)                                                     BOUNDL       19
       UE=U2(KMAX)                                                     BOUNDL       20
       RHOE=RHO2(KMAX)                                                 BOUNDL       21
       PE=P2(KMAX)                                                     BOUNDL       22
       XE=X2(KMAX)                                                     BOUNDL       23
       RAD=R2(KMAX)                                                    BOUNDL       24
       SE=SX(KMAX)                                                     BOUNDL       25
       ANE=1.2                                                         BOUNDL       26
       AMUE=MUEREF*SQRT(TE/1034.)                                      BOUNDL       27
       AMUW=MUEREF*SQRT(TWALL/1034.)                                   BOUNDL       28
       REXI=UE*SE*RHOE/AMUE                                            BOUNDL       29
       THETAI=.036*SE/(REXI**.2)                                       BOUNDL       30
       DELTI=10.286*THETAI                                             BOUNDL       31
C....CALC SKIN FRICTION: K-S EQ., FLAT PLATE, ZERO PRES GRAD           BOUNDL       32
       RETHI=UE*THETAI*RHOE/AMUE                                       BOUNDL       33
       CFI=1./(17.08*(ALOG10(RETHI))**2+25.11*ALOG10(RETHI)+6.012)     BOUNDL       34
C....CALC FRICTION VELOCITY                                            BOUNDL       35
       RC=82.1                                                         BOUNDL       36
C........REPLACE ZMW(I) WITH CONST MOLECULAR WGT FOR NOW               BOUNDL       37
       RHOW=TE*RHOE/TWALL                                              BOUNDL       38
       UFI=(.5*RHOE*UE*UE*CFI/RHOW)**.5                                BOUNDL       39
C....GENERATE TABLE OF TE/T VS U/UE                                    BOUNDL       40
       CONST=UE*UE*4.973E-08                                           BOUNDL       41
       TTOTE=TE+CONST                                                  BOUNDL       42
       AC=-(TTOTE/TE-1.)                                               BOUNDL       43
       CC=TWALL/TE                                                     BOUNDL       44
       B=TTOTE/TE-CC                                                   BOUNDL       45
C....FINER RESOLUTION FOR DETA<.1                                      BOUNDL       46
       I1=50                                                           BOUNDL       47
       I2=140                                                          BOUNDL       48
       I3=I1+1                                                         BOUNDL       49
       DO 100 J=1,I1                                                   BOUNDL       50
  100  ETA(J)=J/(I1*10.)                                               BOUNDL       51
       DO 101 J=I3,I2                                                  BOUNDL       52
  101  ETA(J)=ETA(I1)+(J-I1)/100.                                      BOUNDL       53
       DETA1=ETA(1)                                                    BOUNDL       54
       DETA2=ETA(I3)-ETA(I1)                                           BOUNDL       55
       DO 102 J=1,I2                                                   BOUNDL       56
  102  TETC(J)=(1./(AC*ETA(J)*ETA(J)+B*(ETA(J)**ANE)+CC))**.5           BOUNDL       57
C....CALC COMP CF/INCOMP CF                                            BOUNDL       58
       SUMT=0.0                                                        BOUNDL       59
       DO 110 J=1,I1                                                   BOUNDL       60
  110  SUMT=SUMT+TETC(J)*DETA1                                         BOUNDL       61
       DO 111 J=I3,I2                                                  BOUNDL       62
  111  SUMT=SUMT+TETC(J)*DETA2                                         BOUNDL       63
       CFCCFI=SUMT*SUMT                                                BOUNDL       64
       CFC=CFCCFI*CFI                                                  BOUNDL       65
C....WALL HEAT TRANSFER AND SHEAR STRESS                               BOUNDL       66
       STAT=.35*CFC                                                    BOUNDL       67
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      QWALL=-STANARHOE*UE*CP*(TTOTE-TWALL)
      TAUWAL=-.5*RHOE*UE*UE*CFL
C.....RETURN POINT FROM FIRST PASS
      IF (IFLAG) 112,500,112
C.....CALC U INCOMP/U FRICT INCOMP
  112 UBUFI(1)=SQRT(2./CFC)*TETC(1)*DETA1
      DO 120 J=2,11
  120 UBUFI(J)=UBUFI(J-1)+SQRT(2./CFC)*TETC(J)*DETA1
      DO 121 J=13,I2
  121 UBUFI(J)=UBUFI(J-1)+SQRT(2./CFC)*TETC(J)*DETA2
C.....CALC CORRESPONDING Y/DELTA, INCOMP
      FACT=1./(EXP((UBUFI(I2)-5.05)/2.5))
      DO 132 J=1,I2
      IF (UBUFI(J).LT.5.0) GO TO 130
      IF(UBUFI(J).LT.13.96) GO TO 131
      YDELI(J)=EXP((UBUFI(J)-5.05)/2.5)*FACT
      GO TO 132
  130 YDELI(J)=UBUFI(J)*FACT
      GO TO 132
  131 YDELI(J)=EXP((UBUFI(J)+3.05)/5.0)*FACT
  132 CONTINUE
C.....NOW HAVE Y/DELTA INCOMP = Y/DELTA COMP VS U/UE & TE/T COMP
C
C.....CALC THETA/DELTA & DISP/DELTA BY TRAPEZOIDAL INTEGRATION
C.....OF U/UE(1-U/UE); (1-U/UE) & Y/DELTA
      SUMD2=0.0
      SUMD1=0.0
      IM=I2-1
      DO 140 J=1,I2
      D1INT(J)=1.-ETA(J)
  140 D2INT(J)=D1INT(J)*ETA(J)
      DO 141 J=1,IM
      SUMD1=SUMD1+(YDELI(J+1)-YDELI(J))*.5*(D1INT(J)+D1INT(J+1))
  141 SUMD2=SUMD2+(YDELI(J+1)-YDELI(J))*.5*(D2INT(J)+D2INT(J+1))
      H12=SUMD1/SUMD2
C.....CALC THETAC FROM MOMENTUM INTEGRAL
      IF (LL.EQ.0) GO TO 142
      THETAC(1)=THETAL(2)
      GO TO 143
  142 THETAC(1)=.1
  143 DELX=SQRT((X2(KMAX)-X(KMAX))**2+(R2(KMAX)-R(KMAX))**2)
      DUDX=(UE-U(KMAX))/DELX
      DRHODX=(RHOE-RHO(KMAX))/DELX
      DRDX=(RAD-R(KMAX))/DELX
      AD=(H12+2.)/UE*DUDX+DRHODX/RHOE+DRDX/RAD
      THETAC(2)=(CFC/2.*DELX+THETAC(1))/(1.+AD*DELX)
      DELTAC=THETAC(2)/SUMD2
      DISP=SUMD1*DELTAC
      DO 150 J=1,I2
  150 TETC(J)=1./(TETC(J)*TETC(J))
  500 RETURN
      END
      SUBROUTINE STABLE
C     THIS SUBROUTINE DETERMINES STABLE STEPPING DISTANCE AND PUNCHES
C     OUTPUT DATA WHEN CALLED FOR
C
      COMMON A(25,7)     ,AA(40)      ,ALFA(25,25),ALPHAN      ,ALPHAP
     1       ,ATOL        ,BETAP       ,BMIX        ,C11(25)     ,C(25,40)
     2       ,C12(25)     ,C2(25,40)   ,CABAR(25)   ,CBBAR(25)   ,CP
     3       ,CPS(25)     ,CPSH        ,CSH(25)     ,CSH1(25)    ,CSTREM(25)
     4       ,CSTRM       ,D2IN(25,25),DEFF(25)    ,D2EFF(25)   ,DELTA
     5       ,D11         ,DELSS(40)   ,DELS        ,DELSO       ,DLS(40)
     6       ,DIN(25,25)  ,D12         ,DELY(40)    ,D13         ,DPDY(40)
     7       ,D14         ,DPHIDS(40)  ,EPCON
     8       ,EPSLON      ,EXTRA(50)   ,FSTEP       ,FMAX        ,GRAD
     9       ,H11         ,H(40)       ,HH          ,HJ          ,HPM(25)
     A       ,H2PM(25)    ,H3PM(25)    ,ICONST      ,ICOUNT      ,IDENT(25)
     1       ,IERROR      ,IEXTRA(50)  ,IFLAG       ,IKIND
     2       ,IPTOC       ,ISHOCK      ,ITYPE       ,IPD
     3       ,IDIFF       ,K           ,KAY         ,KAYS        ,KAY2
     4       ,KLO         ,KMAX
     5       ,KUP         ,KP          ,LL          ,LPLANE      ,MA
     6       ,MASH        ,MDOT        ,MMAX        ,MUO         ,MU
     7       ,MU2         ,MUS         ,MW          ,MW2         ,MWSH
     8       ,NMOLED      ,NLS         ,NITER       ,NMAX        ,NN
      COMMON NOCASE      ,OMEGA(25)   ,P11         ,P(40)       ,P12
     1       ,P2(40)                   ,PB(50)      ,PABAR       ,PBBAR
     2       ,PHS         ,P15         ,PHI(40)                  ,PHIB(50)
     3       ,PHISH1      ,PHSTRM                   ,PHIW(50)    ,P18
     4       ,PHI2(40)    ,PHIBS       ,PI          ,PR(25)      ,PSH
     5       ,PSH1        ,PS1         ,PSTREM                   ,PW(50)
     6       ,Q11         ,Q(40)       ,QXTR1       ,QXTR2
     7       ,QW(50)      ,R11         ,R(40)                    ,RB(50)
     8       ,RBS         ,R13         ,RBAR(40)    ,R14         ,R2(40)
     9       ,RCON        ,R15         ,RE(40)      ,RESH        ,R16
     A       ,RHO(40)     ,R17         ,RHO2(40)    ,RHS(25)     ,RHSFN
     1       ,RHSFLP      ,RHABAR      ,RHBBAR      ,RO          ,RSH
     2       ,RSTREM      ,RV          ,R19         ,RW(100)     ,S
     3                    ,SH(50)      ,SC(25)                   ,SW(50)
     4       ,S13         ,SX(40)      ,T11         ,T(40)       ,T12
     5       ,T2(40)      ,TABAR       ,TBBAR       ,TO(25)      ,T14
     6       ,TAW(40)     ,TXTR1       ,TXTR2       ,TOL         ,TSH
     7       ,TSH1        ,TSTREM                   ,TW(50)      ,TWS
     8       ,T5          ,U11         ,U(40)       ,U12         ,U2(40)
      COMMON UXTR1       ,UXTR2       ,U14         ,UBAR(40)    ,USH
     1       ,USH1        ,USTREM                   ,UW(50)      ,UWS
     2       ,X11         ,X(40)       ,X12         ,X2(40)
     3       ,XW(50)      ,XHS         ,XABAR(25)   ,XBBAR(25)   ,X15
     4       ,XS(25,40)   ,XSH         ,XSTREM                   ,XW(50)
     5       ,ZWBAR(40)                ,Y11         ,Y(40)       ,Y12
     6       ,Y2(40)      ,YABAR       ,YBBAR       ,ZA(25)      ,Z11(25)
     7       ,ZJ(25,40)   ,ZWW         ,S2X         ,R2SH        ,X2SH
     8       ,FX(2,40)    ,FR(2,40)    ,FPHI(2,40)  ,FP(2,40)    ,FT(2,40)
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     9     ,FU(2,40)    ,INDL(2,40) ,INDR(2,40) ,FC(2,40,25),CARD1         A       49
     *     ,M           ,N                                                 A       50
      REAL  RAY         ,KAYS(25)   ,KAY2       ,KW         ,MDOT(40)      STABLE   7
     *     ,MA(40)      ,MU         ,MUB(25)    ,MUO(25)    ,MU2           STABLE   8
     *     ,MW(25)      ,MW2        ,MASH       ,MASH1      ,MWSH          STABLE   9
     * ,    MAP                                                            STABLE  10


      COMMON/P11/XMOMV(8), XMOMP(8),ENEP1(8),HEP(40,8),V(40,8),W(40,8),    STABLE  11
     1V2(40,8), W2(40,8), TBODY(8), TP(40,8), TP2(40,8), RP(8),            STABLE  12
     2RHP(40,8), RHP2(40,8) ,ENEP2(8),NBL(8),UM(40)                        STABLE  13
     3,VOLP(8),WTP(8),HC(8),DENG(40,8),ICOND(40,8)                         STABLE  14
      COMMON/P12/FFF,FFG,GAMA,UMI,PO,NPG,KMX,DNOSP(8)                      STABLE  15
       COMMON/P13/CL,CS,IFS,RHSS,WT,HTRAN,SIG,EP,IPART,IKINE,TR(40)        STABLE  16
     1 ,SUPP,SUPPV,SUPPE                                                   STABLE  17
      COMMON/IBUGS1/ IBUGSH                                                STABLE  18
      DIMENSION INDEX2(120)                                                STABLE  19
      COMMON/INIL/XLX,IKI,REX                                              STABLE  20
      COMMON/XYZ/IXYZ,JXYZ                                                 STABLE  21
      DIMENSION CA(30)                                                     STABLE  22
      IXYZ=20                                                              STABLE  23
      JXYZ=0                                                               STABLE  24
      IF (LL) 10,10,40                                                     STABLE  25
C     INDEXING                                                             STABLE  26
   10 IEXTRA(6)=0                                                          STABLE  27
      INI=0                                                                STABLE  28
      DO 20 I=1,KMAX                                                       STABLE  29
   20 INDEX2(I)=I                                                          STABLE  30
      MAX=KMAX+1                                                           STABLE  31
      DO 30 I=MAX,120                                                      STABLE  32
   30 INDEX2(I)=0                                                          STABLE  33
   40 K=2                                                                  STABLE  34
      I=2                                                                  STABLE  35
      DELS=1.0E10                                                          STABLE  36
   45 IF (IEXTRA(5)-LPLANE) 50,50,90                                       STABLE  37
   50 IF (INDEX2(I)) 75,90,90                                              STABLE  38
   75 I=I+1                                                                STABLE  39
      GO TO 50                                                             STABLE  40
C     VISCOUS STABILITY CRITERION                                          STABLE  41
   90 DEL1=DELY(K)*RE(K)/2.0                                               STABLE  42
      IF (IBUGSH.NE.0) WRITE (6,95) DEL1                                   STABLE  43
   95 FORMAT (6H DEL1=,E11.4)                                              STABLE  44
C     INERTIAL STABILITY CRITERION                                         STABLE  45
      IF (MA(K)-1.0-EPSLON) 100,100,600                                    STABLE  46
  100 WRITE (6,200) K                                                      STABLE  47
  200 FORMAT (25H1FLOW IS SUBSONIC IN TUBE,I5)                             STABLE  48
      CALL PDUMP(A(1,1),N,1)                                               STABLE  49
      CALL EXIT                                                            STABLE  50
  600 DEL2=.5*DELY(K)*(MA(K)**2-1.0)**(.5)                                 STABLE  51
  500 FORMAT (6H DEL2=,E11.4)                                              STABLE  52
      IF (IBUGSH.NE.0) WRITE (6,500) DEL2                                  STABLE  53
      IF (DEL1.EQ.0.0)  GO TO 590                                          STABLE  54
      DELSS(K)=ALPHAH/(1.0/DEL1+1.0/DEL2)                                  STABLE  55
      GO TO 595                                                            STABLE  56
  590 DELSS(K)=ALPHAH*DEL2                                                 STABLE  57
  595 CONTINUE                                                             STABLE  58
C     COMBINING SMALL TUBES                                                STABLE  59
      IF (LL) 608,602,602                                                  STABLE  60
  602 FL=LL                                                                STABLE  61
      FPLANE=LPLANE                                                        STABLE  62
      FMULT=FL/FPLANE                                                      STABLE  63
      GSTEP=FSTEP                                                          STABLE  64
      IF (EXTRA(4).LT.1.E-5) GO TO 604                                     STABLE  65
       FSTEP=GSTEP-(GSTEP-EXTRA(3))*(1.-FMULT)/EXTRA(4)                    STABLE  66
      GO TO 606                                                            STABLE  67


  604 FSTEP=GSTEP                                                          STABLE  68
  608 L=K                                                                  STABLE  69
      CALL COMBO(L)                                                        STABLE  70
      FSTEP=GSTEP                                                          STABLE  71
      IF (L-K) 610,690,620                                                 STABLE  72
  610 K=L                                                                  STABLE  73
      IF (IEXTRA(5)-LPLANE) 630,630,90                                     STABLE  74
  620 K=L-1                                                                STABLE  75
      I=I+1                                                                STABLE  76
      IF (IEXTRA(5)-LPLANE) 630,630,90                                     STABLE  77
  630 IJ=I                                                                 STABLE  78
  640 IJ=IJ-1                                                              STABLE  79
      IF (INDEX2(IJ)) 640,650,650                                          STABLE  80
  650 INDEX2(IJ)=-1                                                        STABLE  81
      IEXTRA(6)=IEXTRA(6)+1                                                STABLE  82
      GO TO 50                                                             STABLE  83
C     AREA CHANGE LIMITATION                                               STABLE  84
  690 DLNA=(SIN(.5*(PHI(K)+PHI(K-1)))/(.5*(R(K)+R(K-1)))*DELTA+(PHI(K)-    STABLE  85
     *PHI(K-1))/(DELY(K))*DELSS(K)                                         STABLE  86
      IF (IBUGSH.NE.0) WRITE (6,695) DLNA,ATOL                             STABLE  87
  695 FORMAT (6H DLNA=,E11.4,7H  ATOL=,E11.4)                              STABLE  88
      IF (ABS(DLNA)-ATOL)  800,800,700                                     STABLE  89
  700 DELSS(K)=DELSS(K)*ATOL/ABS(DLNA)                                     STABLE  90
  800 IF (DELSS(K)-DELS) 900,1000,1000                                     STABLE  91
  900 DELS=DELSS(K)                                                        STABLE  92
      IEXTRA(7)=K                                                          STABLE  93
 1000 IF (IEXTRA(5)-LPLANE) 1025,1025,1050                                 STABLE  94
 1025 INDEX2(I)=K                                                          STABLE  95
      IEXTRA(5)=I                                                          STABLE  96
      I=I+1                                                                STABLE  97
 1050 K=K+1                                                                STABLE  98
      IF (K-KMAX) 45,45,1055                                               STABLE  99
 1055 IF (KMAX-38) 1057,1057,1060                                          STABLE 100
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C      COMBINING SMALLEST TUBE WHEN NUMBER OF TUBES GETS TOO LARGE        STABLE   101
 1057 ITUBE=FSTEP                                                         STABLE   102
      IF (KMAX-ITUBE) 1400,1400,1060                                      STABLE   103
 1060 L=IEXTRA(7)                                                         STABLE   104
      K=L                                                                 STABLE   105
      STORE1=GRAD                                                         STABLE   106
      STORE2=FSTEP                                                        STABLE   107
      STORE3=Y(KMAX)                                                      STABLE   108
      GRAD=10.**10                                                        STABLE   109
      FSTEP=10.**(-10)                                                    STABLE   110
      Y(KMAX)=10.**20                                                     STABLE   111
      CALL COMBO(L)                                                       STABLE   112
      GRAD=STORE1                                                         STABLE   113
      FSTEP=STORE2                                                        STABLE   114
      Y(KMAX)=STORE3                                                      STABLE   115
      K=KMAX+1                                                            STABLE   116
 1063 IF (IEXTRA(5)-LPLANE) 1065,1065,2000                                STABLE   117
 1065 IF (L-IEXTRA(7)) 1085,1080,1080                                     STABLE   118
 1080 I=IEXTRA(8)                                                         STABLE   119
      GO TO 1090                                                          STABLE   120
 1085 I=IEXTRA(8)-1                                                       STABLE   121
 1090 IEXTRA(6)=IEXTRA(6)+1                                               STABLE   122
      JMAX=KMAX+IEXTRA(6)                                                 STABLE   123
      JMIN=I+1                                                            STABLE   124

      J=JMAX                                                              STABLE   125
 1095 INDEX2(J)=INDEX2(J-1)                                               STABLE   126
      J=J-1                                                               STABLE   127
      IF (J-JMIN) 1097,1095,1095                                          STABLE   128
 1097 INDEX2(I)=-1                                                        STABLE   129
 1400 IF (IEXTRA(5).GT.LPLANE) GO TO 2000                                 STABLE   130
      IF (X2(2).LT. XLX) GO TO 2000                                       STABLE   131
      IF  (X2(2).EQ. XLX) GO TO 1500                                      STABLE   132
      IF (MOD(LL,IEXTRA(5))) 2000,1500,2000                               STABLE   133
C      PUNCHING OUTPUT CARDS                                              STABLE   134
 1500 I=1                                                                 STABLE   135
      IF(INI.EQ.0)                                                        STABLE   136
     *WRITE(7,1600)  X(I),R(I),PHI(I),P(I),T(I),U(I),1,I                  STABLE   137
      IF(INI.EQ.0.OR.INI.NE.0)                                            STABLE   138
     *WRITE(10,1600) X(I),R(I),PHI(I),P(I),T(I),U(I),1,I                  STABLE   139
 1600 FORMAT(6E12.5,2I4)                                                  STABLE   140
      IF(INI.EQ.0)                                                        STABLE   141
     *WRITE(7,1700)  ((C(J,I),J=1,NDS)                                    STABLE   142
      IF(INI.EQ.0.OR.INI.NE.0)                                            STABLE   143
     *WRITE(10,1700) (C(J,I),J=1,NDS)                                     STABLE   144
 1700 FORMAT(8F10.3)                                                      STABLE   145
      KMXX=KMAX+IEXTRA(6)                                                 STABLE   146
      IF (IMARI.LE.1) GO TO 1802                                          STABLE   147
      DO 1701 I=2,KMAX                                                    STABLE   148
      XMV=0.0                                                             STABLE   149
      XM=0.0                                                              STABLE   150
      XMM=0.0                                                             STABLE   151
      RMII=0.0                                                            STABLE   152
      EU=0.0                                                              STABLE   153
      EE=0.0                                                              STABLE   154
      II=I+1                                                              STABLE   155
      DO 31 J=1,NPG                                                       STABLE   156
      XM=XM+RMP2(II,J)*W2(II,J)**2                                        STABLE   157
      XMM=XMM+RMP2(II,J)*(W2(II,J)+V2(II,J))                              STABLE   158
      XMV=XMV+RMP2(II,J)*V2(II,J)**2                                      STABLE   159
      EU=EU+RMP2(II,J)*(W2(II,J)**3/2.0+V2(II,J)**3/2.0)                  STABLE   160
      RMII=RMII+RMP2(II,J)                                                STABLE   161
   31 EE=EE+RMP2(II,J)*TP2(II,J)*CS*(W2(II,J)     +V2(II,J)  )            STABLE   162
      UPI=(XM+RHO (I)*U(I)**2)/(XMM+RHO (I)*U(I))                         STABLE   163
      VPI=SQRT(XMV/(XM+RHO (I)*U(I)**2))                                  STABLE   164
      VP=UPI*(VPI+VPI**2)                                                 STABLE   165
      UP=UPI*(1+VPI)                                                      STABLE   166
      RHOP=(XMM+RHO (I)*U(I))**2/(1.+VPI)/(XM+RHO (I)*U(I)**2)            STABLE   167
      HP=(RHO (I)*U(I)*(H(I)+U(I)**2/(2.*HJ))+EU/HJ+EE)/(XMM+RHO (I)*U(I  STABLE   168
     1))-.5/HJ*((XM+RHO (I)*U(I)**2)/(XMM+RHO (I)*U(I)))**2*(1.+VPI)**2* STABLE   169
     2((1+VPI)**2-3.*VPI)                                                 STABLE   170
      PHIA=PHI(I)+ATAN(VP/UP)                                             STABLE   171
      QA=SQRT(UP**2+VP**2)                                                STABLE   172
      RMTOT=RHO (I)+RMII                                                  STABLE   173
      WRITE(6,202) UP,VP,RHOP,HP,RMTOT,RMII                               STABLE   174
  202 FORMAT(6E12.5)                                                      STABLE   175
      NESP=NDS+NPG                                                        STABLE   176
      NDOP=NDS+1                                                          STABLE   177
      DO 102 J=NDOP,NESP                                                  STABLE   178
      JJ=J-NDS                                                            STABLE   179
  102 CA(J)=RMP2(I-1,JJ)/RMTOT                                            STABLE   180
      DO 103 J=1,NDS                                                      STABLE   181

  103 CA(J)=C(J,I)*RHO(I)/RMTOT                                           STABLE   182
      TL=1.E-4*HP                                                         STABLE   183
      TA=T(K)                                                             STABLE   184
      DO 104 II=1,100                                                     STABLE   185
      HA=0.0                                                              STABLE   186
      EGM=0.0                                                             STABLE   187
      DO 105 J=1,NDS                                                      STABLE   188
      DO 105 JJ=1,EN                                                      STABLE   189
      HA=HA+A(J,JJ)*TA**(JJ-2)*CA(J)                                      STABLE   190
  105 EGM=EGM+A(J,JJ)*FLOAT(JJ-2)*TA**(JJ-3)*CA(J)                        STABLE   191
      HPP=0.0                                                             STABLE   192
      EGP=0.0                                                             STABLE   193
      DO 106 J=NDOP,NESP                                                  STABLE   194
      HPP=HPP+CS*TA*CA(J)                                                 STABLE   195
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  106 DHP=DHP+CS*CA(J)                                                    STABLE   196
      G=HA+HPP-HP                                                         STABLE   197
      IF (ABS(G) .LT. TL) GO TO 107                                       STABLE   198
      DG=DHP+DGH                                                          STABLE   199
      TA=TA-G/DG                                                          STABLE   200
  104 CONTINUE                                                            STABLE   201
      WRITE (6,108) II,HA,HPP,DGH,DHP                                     STABLE   202
  108 FORMAT(8X,50HITERATION DOES NOT CONVERGE TO CORRECT TEMPERATURE  ,  STABLE   203
     1  I4,2X,4HHA= ,1PE10.3,5X,4HHPP=,E10.3,5X,4HDGH=,E10.3,5X,4HDHP=,   STABLE   204
     2 E10.3)                                                             STABLE   205
  107 CONTINUE                                                            STABLE   206
      ZM=0.0                                                              STABLE   207
      DO 109 J=1,EOS                                                      STABLE   208
  109 ZM=ZM+CA(J)/FF(J)                                                   STABLE   209
      [illegible]                                                         STABLE   210
      WRITE(10,1600)X(I),R(I),PHIA,PA,TA,UA,I,I                           STABLE   211
      WRITE(10,1700)(CA(J),J=1,NOSP)                                      STABLE   212
 1701 CONTINUE                                                            STABLE   213
      GO TO 1900                                                          STABLE   214
 1802 DO 1950 I=2,KMAX                                                    STABLE   215
      IF (INDEX2(I)) 1800,1800,1850                                       STABLE   216
 1800 JJ=I                                                                STABLE   217
 1825 JJ=JJ+1                                                             STABLE   218
      II=INDEX2(JJ)                                                       STABLE   219
      IF (II) 1825,1825,1900                                              STABLE   220
 1850 II=INDEX2(I)                                                        STABLE   221
 1900 IF(IKI.EQ.0.OR.IKI.NE.0)                                            STABLE   222
     *WRITE(10,1600) X(II),R(II),PHI(II),P(II),T(II),U(II),I,INDEX2(I)    STABLE   223
      IF(IKI.EQ.0)                                                        STABLE   224
     *WRITE(7,1600)  X(II),R(II),PHI(II),P(II),T(II),U(II),I,INDEX2(I)    STABLE   225
      IF(IKI.EQ.0)                                                        STABLE   226
     *WRITE(7,1700) (C(J,II),J=1,NS)                                      STABLE   227
      IF(IKI.EQ.0.OR.IKI.NE.0)                                            STABLE   228
     *WRITE(10,1700)(C(J,II),J=1,NOS)                                     STABLE   229
 1950 CONTINUE                                                            STABLE   230
 1960 IEXTRA(6)=0                                                         STABLE   231
      DO 1970 I=2,KMAX                                                    STABLE   232
 1970 INDEX2(I)=I                                                         STABLE   233
      KMAX=KMAX+1                                                         STABLE   234
      DO 1980 I=KMAX,121                                                  STABLE   235
 1980 INDEX2(I)=0                                                         STABLE   236
 2000 IF (IHUGSH.EQ.0) RETURN                                             STABLE   237
      DO 2200 K=2,KMAX                                                    STABLE   238


      WRITE (6,2100) EELSS(K)                                             STABLE   239
 2100 FORMAT (7H EELSS=,E11.4)                                            STABLE   240
 2200 CONTINUE                                                            STABLE   241
      RETURN                                                              STABLE   242
      END                                                                 STABLE   243

      SUBROUTINE PUTIN                                                    PUTIN      2
C     THIS SUBROUTINE READS IN AND INITIALIZES ALL DATA EXCEPT THAT       PUTIN      3
C     HAVING TO DO WITH AN EXTERNAL NON-UNIFORM FLOW FIELD                PUTIN      4
      COMMON A(25,7)      ,AA(40)      ,ALFA(25,25),ALPHAN     ,ALPHAP    A          2
     1       ,ATOL        ,BETAP       ,BMIX       ,C11(25)    ,C(25,40)  A          3
     2       ,C12(25)     ,C2(25,40)   ,CABAR(25)  ,CBBAR(25)  ,CP        A          4
     3       ,CPS(25)     ,CPSH        ,CSH(25)    ,CSH1(25)   ,CSTREP(25) A         5
     4       ,CXSTAR      ,D2IN(25,25),DEFF(25)    ,D2EFF(25)  ,DELTA     A          6
     5       ,D11         ,EELSS(40)   ,DELS       ,DELSO      ,DLS(40)   A          7
     6       ,DIN(25,25)  ,D12         ,DELY(40)   ,D13        ,DPDY(40)  A          8
     7       ,D14         ,DPHIDS(40)  ,EPCON                              A          9
     8       ,EPSLON      ,EXTRA(50)   ,FSTEP      ,FMAX       ,GRAD      A         10
     9       ,H11         ,H(40)       ,HH         ,HJ         ,HPM(25)   A         11
     *       ,H2FM(25)    ,HSPR(25)    ,ICONST     ,ICOUNT     ,IDENT(25) A         12
     1       ,IERROR      ,IEXTRA(50)  ,IFLAG      ,IKIND                 A         13
     2       ,IPLOC       ,ISHOCK      ,ITYPE      ,IPO                   A         14
     3       ,IDIFF       ,K           ,KAY        ,KAYS       ,KAY2      A         15
     4       ,KLO         ,KMAX                                           A         16
     5       ,KOP         ,KS          ,LL         ,LPLANE     ,MA        A         17
     6       ,MASH        ,[illegible] ,MMAX       ,M00        ,M0        A         18
     7       ,M02         ,NCS         ,NA         ,M72        ,NASH      A         19
     8       ,[illegible] ,NCS         ,NITER      ,NMAX       ,NN        A         20
      COMMON  NOCASE      ,OMEGA(25)   ,P11        ,P(40)      ,P12       A         21
     1       ,P2(40)                   ,PB(50)     ,PABAR      ,PBBAR     A         22
     2       ,PBS         ,P15         ,PHI(40)                ,PHIB(50)  A         23
     3       ,PHISH1      ,PHSTRP                  ,PHIK(50)   ,P1B       A         24
     4       ,PHI2(40)    ,PHIPS       ,PI         ,PR(25)     ,PSH       A         25
     5       ,PSH1        ,PS1         ,PSTREP                 ,PW(50)    A         26
     6       ,Q11         ,Q(40)       ,QXTR1      ,QXTR2                 A         27
     7       ,QW(50)      ,R11         ,R(40)                  ,RB(50)    A         28
     8       ,RBS         ,R13         ,RBAR(40)   ,R14        ,R2(40)    A         29
     9       ,RCON        ,R15         ,RE(40)     ,RESH       ,R1B       A         30
     *       ,RHO(40)     ,R17         ,RHO2(40)   ,RHS(25)    ,RHSEN     A         31
     1       ,RHSXD       ,RHABAR      ,RHBBAR     ,RO         ,RSH       A         32
     2       ,RSTREP      ,RV          ,R19        ,RW(100)    ,S         A         33
     3                    ,SB(50)      ,SC(25)                 ,SW(50)    A         34
     4       ,S13         ,SX(40)      ,T11        ,T(40)      ,T12       A         35
     5       ,T2(40)      ,TABAR       ,TBBAR      ,T0(25)     ,T14       A         36
     6       ,TAA(40)     ,TXTR1       ,TXTR2      ,TOL        ,TSH       A         37
     7       ,TSH1        ,TSTREP                  ,TW(50)     ,TAS       A         38
     8       ,TS          ,U11         ,U(40)      ,U12        ,U2(40)    A         39
      COMMON UXTR1        ,UXTR2       ,U14        ,UBAR(40)   ,USH       A         40
     1       ,USH1        ,USTREP                  ,UW(50)     ,UAS       A         41
     2       ,X11         ,X(40)       ,X12        ,X2(40)                A         42
     3       ,XB(50)      ,XBS         ,XABAR(25)  ,XBBAR(25)  ,X15       A         43
     4       ,XS(25,40)   ,XSH         ,XSTREP                 ,XW(50)    A         44
     5       ,ZMAX(40)                 ,Y11        ,Y(40)      ,Y12       A         45
     6       ,Y2(40)      ,YABAR       ,YBBAR      ,ZA(25)     ,Z11(25)   A         46
     7       ,Z3(25,40)   ,ZBW         ,S2X        ,K2SH       ,X2SH      A         47
     8       ,FX(2,40)    ,FR(2,40)    ,FPHI(2,40) ,FP(2,40)   ,FT(2,40)  A         48
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     *        ,FU(2,40)     ,INCL(2,40) ,INDR(2,40) ,FC(2,40,25),CARD1             A        49
     *        ,M            ,N                                                      A        50
      REAL     KAY          ,KAYS(25)     ,KAY2        ,KM          ,MOUT(40)       PUTIN     6
     *        ,MA(40)       ,MU           ,MUS(25)     ,MUO(25)     ,MU2            PUTIN     7
     *        ,MA(25)       ,MM2          ,MASH        ,MASH1       ,MMSH           PUTIN     8
     *  ,      MAP                                                                  PUTIN     9
      COMMON/PT1/SHOMV(8), XHOMP(8),ENEP1(8),REP(40,8),V(40,8),A(40,8),            PUTIN    10

     1V2(40,8), X2(40,8), IRHOT(8), IP(40,8), IP2(40,8), RP(8),                     PUTIN    11
     2RMP(40,8), RMP2(40,8) ,ENEP2(8),RRL(8),UM(40)                                 PUTIN    12
     3,VOLP(8),RTP(8),RL(8),BENG(40,8),ICORD(40,8)                                  PUTIN    13
      COMMON/PT2/FFF,FFG,GAMA,UMI,PU,RPG,RMX,UNDSP(8)                               PUTIN    14
      COMMON/PT3/CL,CS,TPS,RMS9,NT,NIRAN,SIG,EP,IPART,IKINE,TR(40)                  PUTIN    15
     1 ,SURP,SURPV,SURPE                                                            PUTIN    16
      COMMON/IHUGS1/ IHUGSH                                                         PUTIN    17
      COMMON/CHEM1/ ZIG(5), IRR(40),IRI(40),RC(40,3),IRRR(40,5),                    PUTIN    18
     1 AV,CM(26,26),FI(26),AP(26),                                                  PUTIN    19
     2 AM(26),ADOT(26,40),CSI(26),DX(26)                                            PUTIN    20
      COMMON/INPUX/IID,X0,Y0,FRAC  ,KFL                                             PUTIN    21
      COMMON/TRNSP1/ ALFTD(25),DEXP(25)                                             PUTIN    22
      COMMON/INPHO/ ICSH,IIN                                                        PUTIN    23
      EQUIVALENCE (IVISC,IEXTRA(1)),(IPCH,IEXTRA(5))                                PUTIN    24
      COMMON/IGSHOP/ FLO,TOO,UOO,PHOO,COO(25)                                       PUTIN    25
      COMMON/SHOPOT/ XSHM,RSHM,PSIM,PSHM,TSHM,USHM,CSHM(25)                         PUTIN    26
      COMMON/INIL/ XEX,INI,REX                                                      PUTIN    27
      COMMON/TURMUL/TLE,TPR,EDDYK,ITURB,DELMIX                                      PUTIN    28
      COMMON/CFF/IPIO                                                               PUTIN    29
      COMMON/ALM/XLMD                                                               PUTIN    30
      COMMON/XYZ/IXYZ,JXYZ                                                          PUTIN    31
      COMMON/PERGFF/PERGF                                                           PUTIN    32
      COMMON/BLFG/ IBLFLG,IBL                                                       25SEPT   18
      COMMON/WALL/ TWALL                                                            PUTIN    34
      DIMENSION AR(7)                                                               PUTIN    35
      EQUIVALENCE (MASE,EXTRA(11)),(ITAPES,IEXTRA(2))                               PUTIN    36
      IXYZ=21                                                                       PUTIN    37
      JXYZ=0                                                                        PUTIN    38
      IIN=0                                                                         PUTIN    39
C     INTEGRAL PARAMETERS,LIMITS,AND SWITCHES                                       PUTIN    40
      CARD1 = 1.                                                                    PUTIN    41
      READ (5,100) ITYPE,IKIND,IPG,IPTOC,ISHOCK,IHUGSH,IID,ICSH,                    PUTIN    42
     *  ITAPES,IPART,IFI,ITURB,IPIO                                                 PUTIN    43
      READ (5,100) KMAX,NN,KP,MMAX,NMAX,NOS,NITER,LPLANE,IKINE,IPCH,KMN             PUTIN    44
  100 FORMAT (16I5)                                                                 PUTIN    45
      WRITE (6,610) KMAX,NN,KP,IP,ITYPE,IKIND,MMAX,NMAX,NOS,IPG,NITER,              PUTIN    46
     2  ICIFF,LPLANE,IPTOC,IPCH,ISHOCK,IHUGSH,IID,ICSH,ITAPES,IKINE,                PUTIN    47
     3  IPART,IFI,ITURB,IPIO                                                        PUTIN    48
  151 IF (INI.EQ.0) GO TO 150                                                       PUTIN    49
      REWIND 9                                                                      PUTIN    50
      REWIND 10                                                                     PUTIN    51
      DO 5565 I=1,NOS                                                               PUTIN    52
 5565 READ (9,201) (A(I,J),J=1,NN),CSI(I)                                           PUTIN    53
      DO 5566 I=1,NOS                                                               PUTIN    54
 5566 READ (9,400) IDENT(I),MDOT(I),TO(I),OMEGA(I),PR(I),SC(I),MA(I)                PUTIN    55
      READ(9,3) XLMD                                                                PUTIN    56
    3 FORMAT(E12.5)                                                                 PUTIN    57
      READ (9,101) KMAX,DELMIX                                                      PUTIN    58
  101 FORMAT (I2,2E12.5)                                                            PUTIN    59
  150 EXTRA(3)=KMAX                                                                 PUTIN    60
      KFL=KMAX                                                                      PUTIN    61
      ALPHAP=KP                                                                     PUTIN    62
C     PHYSICAL CONSTANTS AND CONVERSIONS                                            PUTIN    63
      RJ=4.182E07                                                                   PUTIN    64
      RETAP=1.013E06                                                                PUTIN    65
      RCON=1.9871                                                                   PUTIN    66
      WRITE (6,611) RETAP,RJ,RCON                                                   PUTIN    67

  611 FORMAT(6E12.4)
C     READ WALL TEMP AND PRINT FLAG FOR NOZZLE                                      PUTIN    68
      READ(5,202) TWALL,IBLFLG,IBL                                                  PUTIN    69
  202 FORMAT (F5.0,2X,I1,2X,I1)                                                     25SEPT   19
C     NON-INTEGRAL PARAMETERS                                                       25SEPT   20
      READ (5,250) ALPHAM,EPSLON,TOL,DELTA,ATOL,FSTEP,GRAD,FRAC,FRACIN              PUTIN    72
      WRITE(6,612) ALPHAM,EPSLON,TOL,DELTA,ATOL,FSTEP,GRAD,FRAC,FRACIN              PUTIN    73
  250 FORMAT (8F9.4,1F8.4)                                                          PUTIN    74
      EXTRA(4)=FRACIN                                                               PUTIN    75
      IF (IID) 260,270,260                                                          PUTIN    76
  260 READ (5,1600) (ALFTD(I),I=1,NOS)                                              PUTIN    77
      READ (5,1600) ( DEXP(I),I=1,NOS)                                              PUTIN    78
      WRITE (6,613)                                                                 PUTIN    79
      DO 614 I=1,NOS                                                                PUTIN    80
  614 WRITE (6,615) I,ALFTD(I),DEXP(I)                                              PUTIN    81
  270 PI=3.1415926                                                                  PUTIN    82
      RU=RCON*RJ                                                                    PUTIN    83
      RV=RU/RETAP                                                                   PUTIN    84
C     ENTHALPY POLYNOMIAL CONSTANTS                                                 PUTIN    85
      IF (INI.NE.0) GO TO 5563                                                      PUTIN    86
      DO 300 I=1,NOS                                                                PUTIN    87
      READ (5,201) (A(I,J),J=1,NN),CSI(I)                                           PUTIN    88
  300 WRITE(9,201) (A(I,J),J=1,NN),CSI(I)                                           PUTIN    89
 5563 CONTINUE                                                                      PUTIN    90
  201 FORMAT(4E13.5/3E13.5)                                                         PUTIN    91
      DO 501 IK=1,6                                                                 PUTIN    92
  501 AR(IK)=0.0                                                                    PUTIN    93
C     TRANSPORT PROPERTIES                                                          PUTIN    94
      IVISC=0                                                                       PUTIN    95
      WRITE (6,616)                                                                 PUTIN    96
      DO 350 I=1,NOS                                                                PUTIN    97
      IF (IPI.LT.0) GO TO 5562                                                      PUTIN    98
                                                                                    PUTIN    99
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      READ (5,400) IDENT(I),MUO(I),TO(I),OMEGA(I),PR(I),SC(I),MW(I)
      WRITE(9,400) IDENT(I),MUO(I),TO(I),OMEGA(I),PR(I),SC(I),MW(I)
 5502 WRITE(6,617) IDENT(I),MUO(I),TO(I),OMEGA(I),PR(I),SC(I),MW(I)
      DO 5501 JN=1,6
      AN(JN)=A(I,JN)
 5501 CONTINUE
      A(I,1)=-AN(5)*1.0E+6/MW(I)
      A(I,2)=AN(6)/MW(I)*1000.0
      A(I,3)=AN(1)/MW(I)
      A(I,4)=AN(2)/(2.0E3*MW(I))
      A(I,5)=AN(3)/(3.0E6*MW(I))
      A(I,6)=AN(4)/(4.0E9*MW(I))
      CSI(I)=CSI(I)/MW(I)
  350 CONTINUE
      DO 340 J=4,NN
      DO 340 I=1,NOS
      IF(A(I,1)) 330,351,330
  351 IF (A(I,J)) 330,340,330
  330 ICPNSI=1
  340 CONTINUE
  400 FORMAT(A4,A),5E12.4,1E8.2)
      DELMI=0.0
      IF(ITURB.EQ.0) GO TO 450
      READ(5,6900) ILE,IPR,EDDYN,PENGF
      WRITE(6,618) ILE,IPR,EDDYN,PENGF


  425 FORMAT(4E12.5)
      IVISC=1
      GO TO 650
  450 DO 600 I=1,NOS
      IF (MUO(I)) 500,600,500
  500 IVISC=1
  600 CONTINUE
      IF(ITURB.EQ.0.AND.IPART.NE.0) IVISC =0
  650 MU=10.0**(-20)
      MU2=10.0**(-20)
C     INNER STREAMLINE POSITION
 1100 K=1
      IF (IRI.EQ.0) READ (5,200) X(K),R(K),PHI(K)
      WRITE(6,619)
      IF (IRI.NE.0) READ (9,200) X(K),R(K),PHI(K)
      WRITE(6,620) K,X(K),R(K),PHI(K)
      X0=X(K)
      Y(K)=0.0
C     OTHER STREAMLINE POSITION AND STREAMTUBE PROPER
      K=2
 1200 CONTINUE
      IF (IRI.EQ.0) READ(5,200) X(K),R(K),PHI(K),P(K),T(K),U(K)
      IF (IRI.NE.0) READ(9,200) X(K),R(K),PHI(K),P(K),T(K),U(K)
      WRITE(6,620) K,X(K),R(K),PHI(K),P(K),T(K),U(K)
      H=SQRT((X(K)-X(K-1))**2+(R(K)-R(K-1))**2)
      IF (ABS(PHI(K)-PHI(K-1))-1.0E-06) 1300,1300,1400
 1300 DELY(K)=H
      GO TO 1500
 1400 DELY(K)=(PHI(K)-PHI(K-1))*H/(2.0*SIN(.5*(PHI(K)-PHI(K-1))))
 1500 AA(K)=PI*(R(K)+R(K-1))**DELTA*DELY(K)
      Y(K)=Y(K-1)+DELY(K)
C     STREAMTUBE COMPOSITION (SPECIES MASS FRACTIONS)
      IF (IRI.EQ.0) READ(5,1600) (C(I,K),I=1,NOS)
      IF (IRI.NE.0) READ(9,1600) (C(I,K),I=1,NOS)
 1600 FORMAT(8E10.3)
C     SETUP CALCULATIONS
 1900 ZMW=0.0
      DO 2000 I=1,NOS
 2000 ZMW=ZMW+C(I,K)/MW(I)
      ZMW=1.0/ZMW
      ZMWK(K)=ZMW
      DO 2100 I=1,NOS
 2100 XS(I,K)=C(I,K)*ZMW/MW(I)
 2200 RHO(K)=ZMW*P(K)/(RV*T(K))
      RMAP=RHO(K)
      MDOT(K)=RHO(K)*U(K)*AA(K)
      FMAX=1.0
      MAX=0.0
      DO 2403 I=1,NOS
      DO 2405 J=1,NT
      EIN(I,J)=0.0
 2405 CONTINUE
 2403 CONTINUE
      IF (IVISC) 2406,2402,2406
 2402 DO 2404 I=1,NOS
      CPS(I)=0.0
      DO 2404 J=1,NN


 2404 CPS(I)=CPS(I)+FLOAT(J-2)*A(I,J)*T(K)**(J-3)
      GO TO 2408
 2406 INIG=1
      MULT=0
      CALL TRANSP(T(K),P(K),K,MULT,IBIG)
 2408 CP=0.0
      DO 2410 I=1,NOS
 2410 CP=CP+CPS(I)*C(I,K)
      IF (MAT-MAX) 2430,2430,2420
 2420 FMAX=MAT/(CP*MU)
 2430 DO 2450 I=1,NOS
      MAX=1
      DO 2450 J=1,MAX
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      IF (UIM(I,J)*RHO(K)/MU-FMAX) 2450,2450,2440
 2440 FMAX=UIM(I,J)*RHO(K)/MU
 2450 CONTINUE
      RE(K)=RHO(K)*U(K)*DELY(K)/(MU*FMAX)
      MA(K)=U(K)*SQRT((CP*ZMW-RCON)/(CP*T(K)*RCON))
      GAMA=CP/(CP-RCON/ZMW )
      PR= 4.0*GAMA/(9.*GAMA-5.0)
      H(K)=0.0
      DO 2500 I=1,NDS
      DO 2500 J=1,NN
 2500 H(K)=H(K)+A(I,J)*C(I,K)*T(K)**(J-2)
      IF (K-KMAX) 2600,2700,2700
 2600 K=K+1
      GO TO 1200
 2700 YO=Y(KMAX)
      HE=H(KMAX)
C     WALL CONDITIONS
      IF (IKI.NE.0) GO TO 2801
      WRITE(6,621)
      DO 2800 I=1,MMAX
      READ  (5,200) XW(I),RW(I),PHIW(I),PW(I),SW(I)
 2800 WRITE (6,620) I,XW(I),RW(I),PHIW(I),PW(I),SW(I)
      GO TO 3700
 2801 READ (9,200) XW(1),RW(1),XW(2),RW(2)
 3700 SWA=0.0
      PHSWA=0.0
      M=1
      PWSM=PW(M)
      IPHIW=PHIW(M)
      IF(IPHIW   ) 3900,3800,3900
 3800 PHIW(M)=PHI(M)
 3900 M=M+1
      IPHIW=PHIW(M)
      IF(IPHIW   ) 4300,4000,4300
 4000 IF (M-MMAX) 4100,4200,4200
 4100 PHIW(M)=ATAN((RW(M+1)-RW(M-1))/(XW(M+1)-XW(M-1)))
      GO TO 4300
 4200 PHIW(M)=2.0*ATAN((RW(M)-RW(M-1))/(XW(M)-XW(M-1)))
      PHIW(M)=PHIW(M)-PHIW(M-1)
 4300 ISW=SW(M)
      IF(ISW   ) 4800,4400,4800
 4400 FKW=(SIN(PHIW(M))-SIN(PHIW(M-1)))/(XW(M)-XW(M-1))
      IF (ABS(FKW/(XW(M)-XW(M-1)))-1.E-06) 4600,4600,4500
 4500 DELSWA=(PHIW(M)-PHIW(M-1))/FKW


      GO TO 4700
 4600 DELSWA=SQRT((XW(M)-XW(M-1))**2+(RW(M)-RW(M-1))**2)
 4700 SWA=SWA+DELSWA
      SW(M)=SWA
 4800 IF (M-MMAX) 3900,4900,4900
 4900 IF (IKI.NE.0) GO TO 4901
      WRITE (6,623)
      DO 5000 N=1,NMAX
      READ (5,200) XB(N),RB(N),PHIB(N),PB(N),SB(N)
 5000 WRITE (6,620) N,XB(N),RB(N),PHIB(N),PB(N),SB(N)
      GO TO 5700
 4901 READ (9,200) XB(1),RB(1),XB(2),RB(2)
 5700 SBA=0.0
C     INNER BOUNDARY CONDITIONS
      N=1
      IPHIB=PHIB(N)
      IF(IPHIB   ) 5900,5800,5900
 5800 PHIB(N)=PHI(KMAX)
 5900 N=N+1
      IPHIB=PHIB(N)
      IF(IPHIB   ) 6300,6000,6300
 6000 IF (N-NMAX) 6100,6200,6200
 6100 PHIB(N)=ATAN((RB(N+1)-RB(N-1))/(XB(N+1)-XB(N-1)))
      GO TO 6300
 6200 PHIB(N)=2.0*ATAN((RB(N)-RB(N-1))/(XB(N)-XB(N-1)))
      PHIB(N)=PHIB(N)-PHIB(N-1)
 6300 ISB=SB(N)
      IF(ISB   ) 6750,6400,6750
 6400 FKB=(SIN(PHIB(N))-SIN(PHIB(N-1)))/(XB(N)-XB(N-1))
      IF (ABS(FKB/(XB(N)-XB(N-1)))-1.E-06) 6600,6600,6500
 6500 DELSBA=(PHIB(N)-PHIB(N-1))/FKB
      GO TO 6700
 6600 DELSBA=SQRT((XB(N)-XB(N-1))**2+(RB(N)-RB(N-1))**2)
 6700 SBA=SBA+DELSBA
      SB(N)=SBA
 6750 IF (N-NMAX) 5900,6800,6800
 6800 IF (IKIND-3) 6905,6850,6850
C     CONDITIONS BEHIND OUTER SHOCK
 6850 CONTINUE
      IF (IKI.EQ.0) READ(5,200) XSH,RSH,PSI,PSH,TSH,USH
      IF(IKI.EQ.0) READ(5,1600)(CSH(I),I=1,NDS)
      IF (IKI.NE.0) READ(9,200) XSH,RSH,PSI,PSH,TSH,USH
      WRITE (6,624) XSH,RSH,PSI,PSH,TSH,USH
      IF(IKI.NE.0) READ(9,1600)(CSH(I),I=1,NDS)
 6900 FORMAT(8E10.3)
      PHS=PSH
C     EXTERNAL FLOW PROPERTIES AT FIRST SHOCK POINT
 6901 READ (5,200) XSTREM,RSTREM,PHSTRM,PSTREM,TSTREM,USTREM
      WRITE (6,625) XSTREM,RSTREM,PHSTRM,PSTREM,TSTREM,USTREM
      READ (5,6900) (CSTREM(I),I=1,NDS)
 6905 IF (ITYPE-3) 7000,6910,6910
C     CONDITIONS BEHIND INNER SHOCK
 6910 CONTINUE
      IF (IKI.EQ.0) READ (5,200) XSHW,RSHW,PSIW,PSHW,TSHW,USHW
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      IF (DIM(I,J)*RHO(K)/MU-FMAX) 2450,2450,2440              PUTIN   195
 2440 FMAX=DIM(I,J)*RHO(K)/MU                                  PUTIN   196
 2450 CONTINUE                                                 PUTIN   197
      RE(K)=RHO(K)*U(K)*DELY(K)/(MU*FMAX)                      PUTIN   198
      MA(K)=U(K)*SQRT((CP*ZMW-RCON)/(CP*T(K)*RU))              PUTIN   199
      GAMA=CP/(CP-RCON/ZMW )                                   PUTIN   200
      PU= 4.0*GAMA/(9.*GAMA-5.0)                               PUTIN   201
      H(K)=0.0                                                 PUTIN   202
      DO 2500 I=1,NOS                                          PUTIN   203
      DO 2500 J=1,NN                                           PUTIN   204
 2500 H(K)=H(K)+A(I,J)*C(I,K)*T(K)**(J-2)                      PUTIN   205
      IF (K-KMAX) 2600,2700,2700                               PUTIN   206
 2600 K=K+1                                                    PUTIN   207
      GO TO 1200                                               PUTIN   208
 2700 YO=Y(KMAX)                                               PUTIN   209
      HE=H(KMAX)                                               PUTIN   210
C     WALL CONDITIONS                                          PUTIN   211
      IF (IKI.NE.0) GO TO 2801                                 PUTIN   212
      WRITE(6,621)                                             PUTIN   213
      DO 2800 I=1,MMAX                                         PUTIN   214
      READ  (5,200) XW(I),RW(I),PHIW(I),PW(I),SW(I)            PUTIN   215
 2800 WRITE (6,620) I,XW(I),RW(I),PHIW(I),PW(I),SW(I)          PUTIN   216
      GO TO 3700                                               PUTIN   217
 2801 READ (9,200) XW(1),RW(1),XW(2),RW(2)                     PUTIN   218
 3700 SWA=0.0                                                  PUTIN   219
      PHSWA=0.0                                                PUTIN   220
      M=1                                                      PUTIN   221
      PWSH=PW(M)                                               PUTIN   222
      IPHIW=PHIW(M)                                            PUTIN   223
      IF(IPHIW   ) 3900,3800,3900                              PUTIN   224
 3800 PHIW(M)=PHI(M)                                           PUTIN   225
 3900 M=M+1                                                    PUTIN   226
      IPHIW=PHIW(M)                                            PUTIN   227
      IF(IPHIW   ) 4300,4000,4300                              PUTIN   228
 4000 IF (M-MMAX) 4100,4200,4200                               PUTIN   229
 4100 PHIW(M)=ATAN((RW(M+1)-RW(M-1))/(XW(M+1)-XW(M-1)))        PUTIN   230
      GO TO 4300                                               PUTIN   231
 4200 PHIW(M)=2.0*ATAN((RW(M)-RW(M-1))/(XW(M)-XW(M-1)))        PUTIN   232
      PHIW(M)=PHIW(M)-PHIW(M-1)                                PUTIN   233
 4300 ISW=SW(M)                                                PUTIN   234
      IF(ISW   ) 4800,4400,4800                                PUTIN   235
 4400 FWA=(SIN(PHIW(M))-SIN(PHIW(M-1)))/(XW(M)-XW(M-1))        PUTIN   236
      IF (ABS(FWA/(XW(M)-XW(M-1)))-1.E-06) 4600,4600,4500      PUTIN   237
 4500 DELSWA=(PHIW(M)-PHIW(M-1))/FWA                           PUTIN   238

      GO TO 4700                                               PUTIN   239
 4600 DELSWA=SQRT((XW(M)-XW(M-1))**2+(RW(M)-RW(M-1))**2)       PUTIN   240
 4700 SWA=SWA+DELSWA                                           PUTIN   241
      SW(M)=SWA                                                PUTIN   242
 4800 IF (M-MMAX) 3900,4900,4900                               PUTIN   243
 4900 IF (IKI.NE.0) GO TO 4901                                 PUTIN   244
      WRITE (6,623)                                            PUTIN   245
      DO 5000 N=1,NMAX                                         PUTIN   246
      READ (5,200) XB(N),RB(N),PHIB(N),PB(N),SB(N)             PUTIN   247
 5000 WRITE (6,620) N,XB(N),RB(N),PHIB(N),PB(N),SB(N)          PUTIN   248
      GO TO 5700                                               PUTIN   249
 4901 READ (9,200) XB(1),RB(1),XB(2),RB(2)                     PUTIN   250
 5700 SBA=0.0                                                  PUTIN   251
C     OUTER BOUNDARY CONDITIONS                                PUTIN   252
      N=1                                                      PUTIN   253
      IPHIB=PHIB(N)                                            PUTIN   254
      IF(IPHIB   ) 5900,5800,5900                              PUTIN   255
 5800 PHIB(N)=PHI(KMAX)                                        PUTIN   256
 5900 N=N+1                                                    PUTIN   257
      IPHIB=PHIB(N)                                            PUTIN   258
      IF(IPHIB   ) 6300,6000,6300                              PUTIN   259
 6000 IF (N-NMAX) 6100,6200,6200                               PUTIN   260
 6100 PHIB(N)=ATAN((RB(N+1)-RB(N-1))/(XB(N+1)-XB(N-1)))        PUTIN   261
      GO TO 6300                                               PUTIN   262
 6200 PHIB(N)=2.0*ATAN((RB(N)-RB(N-1))/(XB(N)-XB(N-1)))        PUTIN   263
      PHIB(N)=PHIB(N)-PHIB(N-1)                                PUTIN   264
 6300 ISB=SB(N)                                                PUTIN   265
      IF(ISB   ) 6750,6400,6750                                PUTIN   266
 6400 FBA=(SIN(PHIB(N))-SIN(PHIB(N-1)))/(XB(N)-XB(N-1))        PUTIN   267
      IF (ABS(FBA/(XB(N)-XB(N-1)))-1.E-06) 6600,6600,6500      PUTIN   268
 6500 DELSBA=(PHIB(N)-PHIB(N-1))/FBA                           PUTIN   269
      GO TO 6700                                               PUTIN   270
 6600 DELSBA=SQRT((XB(N)-XB(N-1))**2+(RB(N)-RB(N-1))**2)       PUTIN   271
 6700 SBA=SBA+DELSBA                                           PUTIN   272
      SB(N)=SBA                                                PUTIN   273
 6750 IF (N-NMAX) 5900,6800,6800                               PUTIN   274
 6800 IF (IKIND-3) 6905,6850,6850                              PUTIN   275
C     CONDITIONS BEHIND OUTER SHOCK                            PUTIN   276
 6850 CONTINUE                                                 PUTIN   277
      IF (IKI.EQ.0) READ(5,200) XSH,RSH,PSI,PSH,TSH,USH        PUTIN   278
      IF(IKI.EQ.0) READ(5,1600)(CSH(I),I=1,NOS)                PUTIN   279
      IF (IKI.NE.0) READ(9,200) XSH,RSH,PSI,PSH,TSH,USH        PUTIN   280
      WRITE (6,624) XSH,RSH,PSI,PSH,TSH,USH                    PUTIN   281
      IF(IKI.NE.0) READ(9,1600)(CSH(I),I=1,NOS)                PUTIN   28
 6900 FORMAT(6E10.3)                                           PUTIN   28
      PHS=PSH                                                  PUTIN   2 4
C     EXTERNAL FLOW PROPERTIES AT FIRST SHOCK POINT            PUTIN   285
 6901 READ (5,200) XSTREM,RSTREM,PHSTRM,PSTREM,TSTREM,USTREM   PUTIN   286
      WRITE (6,625) XSTREM,RSTREM,PHSTRM,PSTREM,TSTREM,USTREM  PUTIN   287
      READ (5,6900) (CSTREM(I),I=1,NOS)                        PUTIN   288
 6905 IF (IKIND-3) 7000,6910,6910                              PUTIN   289
C     CONDITIONS BEHIND INNER SHOCK                            PUTIN   290
 6910 CONTINUE                                                 PUTIN   291
      IF (IKI.EQ.0) READ (5,200) XSHI,RSHI,PSII,PSHI,TSHI,USHI PUTIN   292
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